REHABILITATION OF DEGRADED TROPICAL FORESTS IN INDIA'S WESTERN GHATS: SILVICULTURAL AND SOCIO-ECONOMIC IMPLICATIONS OF MULTIPLE SPECIES PLANTATIONS

By

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With the base of ignorance, reaction arises; with the base of reaction, consciousness arises; with the base of consciousness, mind and body arise; with the base of mind and body, the six senses arise; with the base of the six senses, contact arises; with the base of contact, sensation arises; with the base of sensation, craving and aversion arise; with the base of craving and aversion, attachment arises; with the base of attachment, the process of becoming arises; with the base of the process of becoming, birth arises; with the base of birth, aging and death arise, together with sorrow, lamentation, physical and mental sufferings and tribulations. Thus arises the entire mass of suffering.

With the complete eradication and cessation of ignorance, reaction ceases; with the cessation of reaction, consciousness ceases; with the cessation of consciousness, mind and body cease; with the cessation of mind and body, the six senses cease; with the cessation of the six senses, contact ceases; with the cessation of contact, sensation ceases; with the cessation of sensation, craving and aversion cease; with the cessation of craving and aversion, attachment ceases; with the cessation of attachment, the process of becoming ceases; with the cessation of the process of becoming, birth ceases; with the cessation of birth, aging and death cease, together with sorrow, lamentation, physical and mental sufferings and tribulations. Thus this entire mass of suffering ceases.

- Paticca-samuppada Sutta, Samyutta Nikaya, XII (I). 1.

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REHABILITATION OF DEGRADED TROPICAL FORESTS IN INDIA'S WESTERN GHATS: SILVICULTURAL AND SOCIO-ECONOMIC IMPLICATIONS OF MULTIPLE SPECIES PLANTATIONS

By

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December, 1997

Chairman: Nigel J. H. Smith
Major Department: Geography

This research examines the role of multiple species plantations (MSPs) in rehabilitation of Indian tropical moist deciduous forests, as evaluated by both silvicultural and community resource use criteria.

The silvicultural study investigates the effects of tree species and duration of exposure to understory conditions on shoot growth rates of underplanted tree seedlings. An initial survey conducted in 1990 evaluated shoot height and basal area growth rates of native hardwood seedlings after one, two, and three years of exposure understory conditions in MSPs. Local foresters' opinions about the shade/understory tolerance of many native tree species was also solicited. Using the information, I selected one understory-tolerant and one understory-intolerant species for experimental study. Seedlings of these two species

were experimentally released after one, two, and three years of growth beneath MSPs, and their growth rates measured during one year after release. Growth rates of unreleased control seedlings were also measured over the same one year period. In a second experiment I compared the relative effects of aboveground and belowground competition on shoot growth rates of the understory-tolerant species. The relative effect of soil fertility on seedling shoot growth was also assessed.

The effect of state-managed MSP programs on gender, caste, and age-based use of forest resources forms the forest resource use component of this research. Historical development, ownership, and use of India's timber and non-timber resources in northwestern Karnataka State are first described. Contemporary attitudes towards and use of non-timber forest resources in minor forests - before and after their conversion to MSPs - are then disaggregated by gender, caste, and age. Differential effects of modern state reforestation programs on local resource user groups of interest are derived from two community surveys. Gender and caste-based non-timber resource use priorities that have been neglected in previous state reforestation programs are identified. Joint state forest department-local community negociations centered on collection, presentation, and analysis of spatial data are introduced as a strategy to catalyze and guide future forest resource use decision making.

CHAPTER 1
INTRODUCTION

This work was stimulated by the notion that degraded tropical forest systems can and should be rehabilitated according to ecological principles, without imposing economic hardship on forest-dependent people in the process. While instances of promising tropical reforestation efforts are frequently cited (e.g., Food and Agricultural Organization of the United Nations 1989, Agarwal and Narain 1989, Cernea 1985, Murray 1983, Nesmith 1991, Poffenberger 1990), until recently few programs have emphasized the role of local forest dwellers in program conception, implementation, or enjoyment of the benefits they produce (Ayuwat 1993, Dhar et al. 1990, Malhorta and Poffenburger 1989, Noronha and Spears 1985, Pathan et al. 1990, Singh 1987). How then can reforestation programs in the tropics be ecologically sound while meeting the needs of local people? This two-part question guides the study that follows.

To address both parts of this question field research site selection had to be limited to areas where forest rehabilitation efforts were already underway, and in proximity to rural forest-dependent communities. A two-year search led to the selection of a reforestation site in India's Western Ghats where the application of a dual ecology/community welfare research agenda was deemed feasible. The area is Karnataka State's Uttara Kanada (North Kanara) District, where a multiple species plantation

(MSP) reforestation program is underway. A decade of Karnataka Forest Department (KFD) refinement of MSP techniques over thousands of hectares in North Kanara District was already producing both silvicultural and ecological impacts when this research began in mid-1991.

Two separate but linked sets of research questions were formulated to address the ecological and community welfare impacts of forest rehabilitation using MSP silviculture. The initial focus of this work was to document and test the degree to which MSPs facilitate recovery of North Kanara's tropical moist deciduous forests. The complementary focus centered on two surveys about local perceptions of forest resources and the effect of MSP silviculture on forest-dependent communities in North Kanara.

This research concludes by identifying several ecological merits of MSPs, while documenting that MSPs are often disliked, or at least misunderstood, by local forest dwellers. Local perceptions are shown to vary according to survey informants' caste, gender, and sometimes age. Conclusions drawn from the social surveys provide a framework for understanding differences in local perceptions about forest resources, how they are utilized, and local recommendations for forest rehabilitation.

The remainder of this introductory chapter describes my silvicultural and social survey research agendas, how they are related, and the questions that have guided both inquiries. It also describes the research area, the MSP silvicultural system,

and Terkanahalli Village - where forest resource-use survey data were collected.

Chapters 2 through 4 describe the relevance and specific aims of the silvicultural study, study design and implementation, and study results and associated ecological impacts of MSPs, respectively.

Chapter 5 reviews the historical conflict between the Indian state and local communities over forest resources. Chapters 6 and 7 describe the development of two community forest resource-use surveys, their implementation, and presentation and discussion of survey responses.

Chapter 8 presents a spatial approach to participatory decision-making about future forest resource use. Joint forest department/local community workshops emphasizing the collection, presentation, and analysis of spatial data are introduced as a strategy to catalyze and guide collaborative forest resource management. The ideas for this approach evolved from my collaboration with both foresters and local people in carrying out this dual research agenda.

Forest Rehabilitation and the Needs of Forest-Dependent Communities: A Dual Research Agenda

The ecological importance of Indian forests, their protection and rehabilitation, and the undesirable consequences of their disappearance (Bentley et al. 1987) are well-understood by those who live near the remaining tropical forests of peninsular India (Nair 1984). During the 1980s, concern over the

effects of deforestation of India's watersheds spurred international financing of social forestry programs to reforest 45 million hectares (ha) of degraded Indian uplands. Total recommended outlays to protect India's tropical forest resources amounted to US$ 1.2 billion for 1987-91, or 23 percent of investments recommended to save tropical forests worldwide (World Resources Institute 1985). The primary operational response of Indian state governments to shrinking forest areas has been the conversion of degraded forest lands into plantations. By 1990, India boasted 18,900,000 ha of plantations: a figure that continued to increase by 1,441,000 ha annually during the early 1990s (World Resources Institute 1994). This represents the largest commitment to plantation silviculture in the tropics.

Reforestation efforts notwithstanding, annual rates of deforestation in India increased steadily during the 1980s: 339,000 ha/year for the decade versus 147,000 ha/year for the period 1981-85 (World Resources Institute 1994). Menon (1986) calculated that deforestation rates in the Trichur region of the southern Western Ghats accelerated by 50% between the years 1960 and 1984, compared to 23% for the years from 1930 to 1960. This loss has amounted to a cumulative contraction of Trichur's forest area from 392 km^2 in 1930 to 130 km^2 in 1984.

Concern about Western Ghats deforestation spawned a Karnataka Forestry Department (KFD) initiative in 1982 to rehabilitate deforested sites in an ecologically sound and socially beneficial way (Shyam Sunder et al. 1986). Local foresters call these replanted areas "miscellaneous plantations",

but I have named them multiple species plantations (MSPs) because the technique comprises simultaneous outplanting of numerous native hardwood tree species with faster-growing, nitrogen-fixing, naturalized tree species on degraded sites. These sites are usually located within KFD jurisdictional zones called minor forests: areas where local people have historical non-timber usufruct rights (see Chapter 5 for the history of minor forest designation and utilization). Recurrent, income-generating thinnings of the fast-growing overstory species begin in the seventh year after outplanting. These thinnings progressively remove MSP canopy trees, releasing companion saplings from a shaded understory environment.

Both state foresters and local people have a stake in the successful rehabilitation of degraded forests by using MSP silviculture. Foresters hope to quickly establish several valuable hardwood tree species on non-productive state forest lands, while generating income from commercial thinnings. Local people are the designated beneficiaries of fuelwood, branches, and mulch resulting from plantation thinning operations (Shyam Sunder et al. 1986). If workable, this sharing of benefits will promote the popularity and future success of MSP programs among Karnataka's foresters and villagers alike.

Have MSPs performed as intended since their inception, providing expected benefits to both villagers and foresters? Do MSPs produce undesirable outcomes? And, if so, can MSP silviculture be improved to enhance benefits to both of these groups, and to the Indian environment? These questions guide

both the silvicultural and community forest resource-use portions of this study.

The study's silvicultural component focuses on the effects of species and duration of understory exposure (i.e., how long native hardwood seedlings have been growing beneath a canopy of faster-growing trees) on understory seedlings' shoot growth rates before and after canopy removal. Relative growth rate data, interviews, and personal field observations are used to distinguish the growth characteristics and temporal differences in understory tolerance of two native hardwood species. One species is characterized as tolerant of understory conditions, while the other is less-tolerant (Kadambi 1956). Study results point to management guidelines that maximize seedlings' growth rates after outplanting in MSPs.

The effects of state-managed MSP programs on caste, gender, and, in some cases, age-based use of forests guide the forest resource-use survey component of this research. Historical development, ownership, and use of India's timber and non-timber resources describe the setting in which two surveys were made. Current local knowledge and perceptions of non-timber resources are then analyzed by caste, gender, and age in both surveys - one of 122 and the other of 37 rural informants. These surveys highlight how knowledge of forest resources and perceptions about MSPs vary according to these three variables. The surveys pay special attention to perceptions about unrehabilitated minor forests. Minor forests have been historically available to local people for utilization of non-timber resources. Today they are

uniformly degraded, making them prime candidate sites for government MSP reforestation programs.

The Research Area

The research area is within the Sirsi Forest Division, a management unit in the Kanara Forest Circle of the Karnataka Forest Department (KFD), Uttara Kanada District, India (see Figure 1-1). This Forest Circle contains 8,800 km^2 of state-managed reserved forest (14-15 ^{o} N, 75 ^{o} E), with elevations ranging from 450-900 m above sea level. The seven month monsoon brings 1700-2100 mm of precipitation, mostly between June and September. Mean annual temperature is 27 ^{o}C, mean temperature of the coldest month is 24.5 ^{o}C, and the mean minimum daily temperature of the coldest month is 19 ^{o}C (Pascal 1988). The "Dharwad System" is the name given to the ancient, metalliferous metamorphic rock that underlies the research area. It is rich in iron, manganese, and in some locations in copper, lead, and gold. This matrix rock is derived from "ancient sediments - conglomerates, more or less ferruginous quartzites, greywackes, schists and limestone" (Pascal 1988: 5). A heterogeneous mixture of gneiss and different kinds of intrusive granites also dot the Karnataka Plateau.

Area soils have been classified as eutric nitosols (FAO World Soils Map 1988), or alfisols (Sanchez 1976), and are often paleustalfs, due to their deep argillic horizons and the influence of pronounced wet and dry season moisture fluctuations.

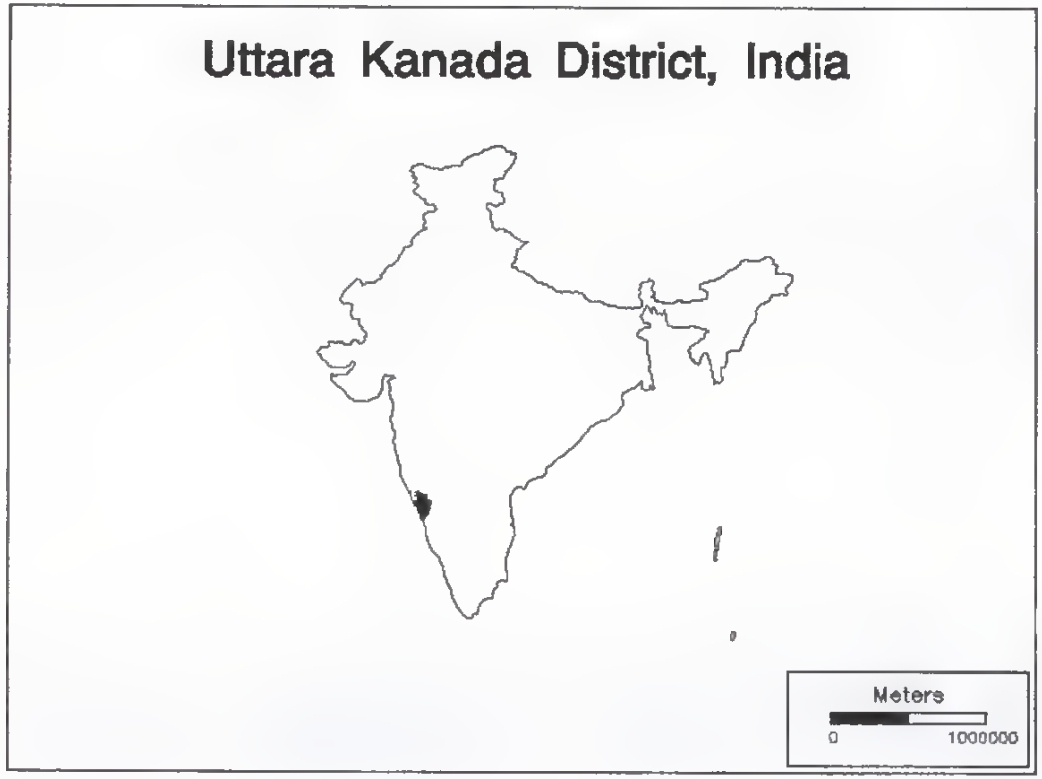


Figure 1-1. Uttara Kanada (North Kanara) District, Karnataka, India

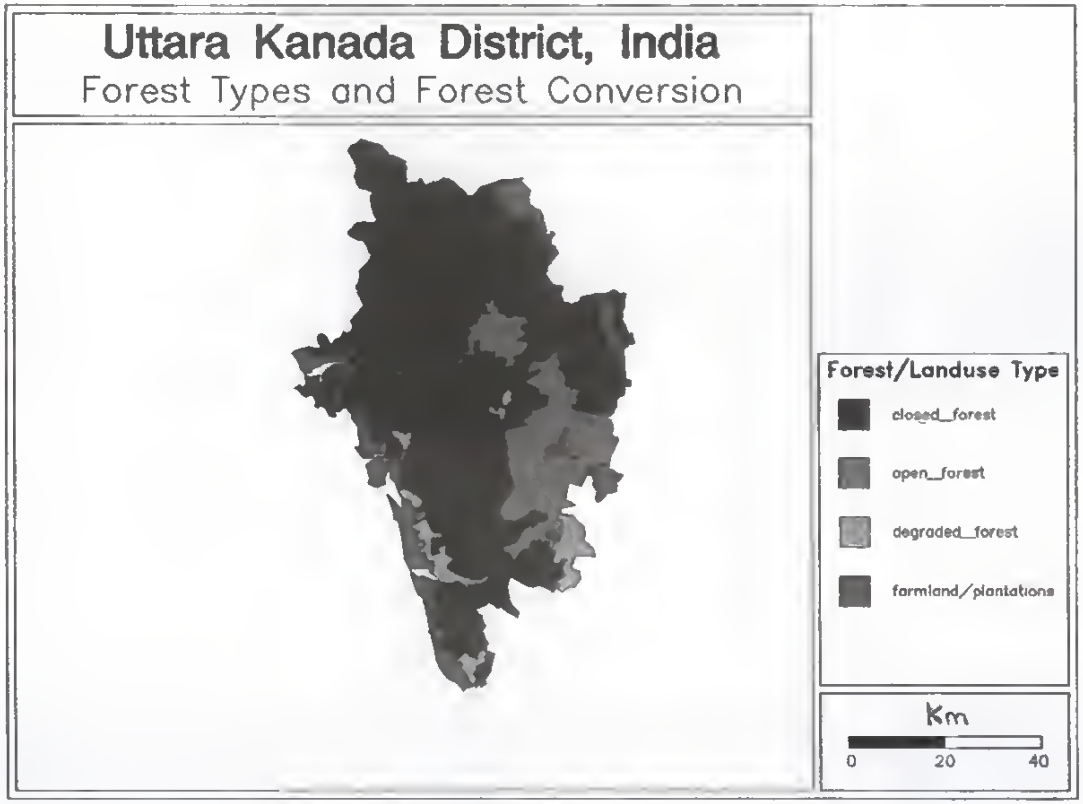


Figure 1-2. Forest types and forest conversion, Uttara Kanada District, Karnataka, India
Source: Karnataka Forest Department, Maps Division, Aranya Bhavan, Bangalore

The largest urban center in the Sirsi Forest Division is Sirsi Town. Sirsi and its surroundings had about 40,000 inhabitants in 1981: a figure that grew to 80,000 by 1992 (Sirsi Tax Collector's Office, pers. com.). Sirsi had a population density of 100-200 persons per km^2 in the mid-1980s (Pascal 1988). Numerous villages dot the countryside outside of Sirsi, each bordered by state reserved forest lands. Terkanahalli Village, where the forest resource use surveys were carried out, is located six km east of Sirsi along Banvasi Road. By Indian standards, Sirsi's environs are not densely populated, helping to explain why three-fourths of this hilly region is still forested (see Figure 1-2).

Multiple Species Plantations (MSPs)

In 1982, Karnataka State Forester A. N. Yellappa Reddy led KFD foresters in adopting MSP silviculture as a promising strategy to rehabilitate degraded forests in northwestern Karnataka. Degraded minor forests are prime candidates for MSP silviculture, because they demonstrate limited ability to naturally regenerate themselves under present use regimes. After being bounded by cattle-exclusion trenches and receiving transplantation holes with downslope water collection pits, these areas are planted with nursery-grown seedlings of *Acacia auriculiformis*, *Casuarina equisetifolia*, or a mixture of these naturalized species. Inter-seedling spacing has varied over the years from one to three meters (10,000 to 1089 stems/ha), according to local site conditions and management objectives.

Both species are known for their rapid initial growth, fuel wood quality, wide range of soil pH tolerance, drought-hardiness, and their ability to fix nitrogen (Davidson et al. 1989, Midgley and Vivekanandan 1986). What distinguishes MSP silviculture is the simultaneous planting of native tropical hardwood species (see Table 1-1) with one or both of these nitrogen-fixing species, hence the term multiple species plantations.

Table 1-1. Native hardwood species often incorporated into Multiple Species Plantations (MSPs)

Species Name	**Family**	**Local Name**
Spondias pinnata	Anacardiaceae	umba'da, hog plum
Wrightia tinctoria	Apocynaceae	hale, dhantappala
Stereospermum xylocarpum	Bignoniaceae	kharisingha, pannimuringa
Bombax ceiba	Bombacaceae	kapok, semul
Cordia McCloudii	Boraginaceae	hadanga
Anogeissus latifolia	Combretaceae	dindal, njama
Terminalia arjuna	Combretaceae	hole matti, kulamaruthu
Terminalia balerica	Combretaceae	tare', thaanni, myrobalan
Terminalia paniculata	Combretaceae	kindal, pullamaruthu
Terminalia tomentosa	Combretaceae	mutti, karimaruthu,
Albizia procera	Fabaceae	siris, jalavaka
Dalbergia latifolia	Fabaceae	sisum, veeti, rosewood
Emblica officinalis	Fabaceae	nelli, myrobalam
Ougenia dalbergioides	Fabaceae	karimut'tul
Pterocarpus marsupium	Fabaceae	honne', venga, bijasal

Table 1-1—continued

Species Name	Family	Local Name
Xylia xylocarpa	Fabaceae	jamba, irul
Lagerstroemia flosreginae	Lythraceae	holedasal, jarul
Lagerstroemia lanceolata	Lythraceae	nundi, venteak
Syzygium cumuni	Myrtaceae	neral, neralu
Adina cordifolia	Rubiaceae	heddi, haldu
Mitragyna parviflora	Rubiaceae	kalum, nirkadambu
Sapindus emarginata	Sapindaceae	antualah, ritha, soapnut
Grewia tiliafolia	Tiliaceae	dardussal, dhaman
Gmelina arborea	Verbenaceae	shivani, gamari
Tectona grandis	Verbenaceae	sagowanni, thekku
Vitex ultisima	Verbenaceae	bharanugi, myla, milla

Presumably, the faster-growing *Acacia* and *Casuarina* seedlings create a protective understory environment for hardwood seedling establishment and growth, while themselves becoming a source of fuelwood and poles. Commercial thinning of *Acacia* and *Casuarina* begins approximately seven years after outplanting. Each successive thinning provides enhanced growing space, releasing hardwood species in the plantation understories. The silvicultural prescription calls for removal of all *Acacia* and *Casuarina* by about the fifteenth year. Due to the initial crowding, the residual mixed stand contains hardwood saplings and poles with straight boles. This MSP approach is favored over planting of native hardwoods alone on exposed mineral soil, since

the absence of *Acacia* and/or *Casuarina* has often resulted in mortality or slowed stem growth of seedlings. Unsuccessful state forest plantations seen by the author at Thirthalli, Karnataka clearly make this point.

Analysis of Sirsi Forest Division office records indicates that from 1984-1992 over 12,000 ha of degraded forests received MSP treatment in the Division. Eighty percent of these MSPs occur on a portion of the Division's 45,000 ha classified as minor forest lands. The remaining MSPs are located within degraded parts of reserve forests. This planting effort covers 30 percent of the total area of previously degraded forests in the Division. Approximately 12,000 ha of degraded forests remain targeted for MSPs. Another 12,000 ha are not sufficiently degraded to warrant MSP treatment at present. Three thousand hectares of degraded forest will not receive MSPs, at the request of local forest dwellers. Explanations for this local attitude towards MSPs will be considered in Chapters 6 through 8 - the forest resource use portion of this study.

Gender and Caste-based Analysis of Forest Resource Use

In their analysis of environmentally sound and participatory development, Agarwal and Narain (1989) redefine rural Indian poverty not as a shortage of cash, but as a shortage of biomass resources to meet basic survival needs. These authors document absolute reductions in biomass productivity over India's non-agricultural lands, contributing to increased poverty among rural people.

Rural women, being the primary managers and processers of biomass resources for subsistence, are often the most immediate victims of deforestation in and around Indian villages (VIKSAT 1990). Women often have the greatest practical knowledge of local biomass resources (Rocheleau 1988, Molnar and Schreiber 1989, FAO 1989), yet are seldom consulted about reforestation projects intended to benefit their families (FAO 1983, Hoskins 1983, Rocheleau 1988, Spring 1988, Williams 1985, Nesmith 1991, Shiva 1988). To become socially-oriented, forestry programs must therefore expand their focus beyond productivity issues to include program impacts on local users of forest resources, particularly women. Women may be excluded from joining forestry programs due to gender-based biases of extension methods (Spring 1988), or because socio-economic constraints make their participation difficult (Hoskins 1983). Such barriers to women's participation must be recognized and consciously addressed if programs are to accommodate all local people.

As with gender, people may be differentially affected by forestry programs on the basis of caste or ethnicity. Caste-based response to MSPs is variable, and is predicated on inter-caste differences in forest resource knowledge and use. Gadgil (1989) describes these caste-based differences in the region of this study, where he found that nine endogamous caste groups have diversified and partitioned their use of forest resources. He cites the following examples: Chamagars make mats and brooms from *Phoenix* palms; Badigars and Holeswars make baskets and rope from *Dendrocalamus strictis* bamboo; Gudigars use sandalwood and other

tree species in woodcarving; Achari use different tree species than Gudigars to make tool handles; Holeya make fishing tackle using *Hemidesmus indicus;* and Maratha and Jadamalli make brooms from *Lantana* camara. Forestry program impacts within particular caste groups are also expected to differ with respect to gender. In some situations a person's age may shape his/her knowledge and opinions about forest resources and their rehabilitation.

This study employs two survey instruments to distinguish differences in local knowledge and use of minor forests, both before and after they are converted to MSPs. The surveys also encourage informants to recommend ways to address their needs when they are adversely affected by MSPs. Together the two surveys attempted to

1) Identify caste and gender-based differences in local community knowledge and use of non-timber forest resources;

2) Identify groups of interest that benefit the most from MSP programs, those groups that benefit the least, and those that remain unaffected;

3) Determine whether MSPs provide enhanced benefits to local gender and caste-based groups when compared to unrehabilitated minor forest lands;

4) Explore how MSP silviculture and management can be altered to benefit critically affected gender and caste groups, those whose subsistence derives from access to and use of forest resources.

Village Study Area

The multi-caste village of Terkanahalli was selected for study of local forest resource use practices. Terkanahalli lies six km east of Sirsi Town on the Banvasi Road. The Sirsi Taluk

Revenue Department maintains birth, death, and land deed records dating from 1825 of the original inhabitants of Terkanahalli Village. A temple there, consecrated to Virabhadra, resembles the architectural style of Belur and Halibid Temples, ca. 1100. This indicates ancient settlement of the site.

The village proper is divided into eight residential groupings, or hamlets, the largest being Terkanahalli Gram. Fourteen caste groups reside in Terkanahalli, making it a mixed-caste village. In 1992, 140 families lived in all of the hamlets, 122 of which were included in the forest products use survey. The average local landholding was approximately 1.0 - 1.2 ha. More than 50 percent of all families were landless, and therefore normally worked as agricultural laborers for land-owning families or the KFD. Some landless people also worked in nearby Sirsi. The largest landholding in the area was a joint family holding of 15 acres. The owners were absentee residents of Sirsi Town.

MSPs are found throughout Terkanahalli, the oldest having been planted in 1987. Villagers are therefore familiar with this silvicultural innovation of the KFD. While local opinions vary concerning the specific impacts of MSPs on village life, there is consensus that MSPs are speeding the depletion of valuable non-timber forest resources. Reduced biodiversity and tenure/usufruct explanations for this loss clearly emerge from the community forest resource use study. Remedies to this problem are suggested by survey informants, and these form the basis for a participatory forest resource management model presented in the concluding chapter of this dissertation.

CHAPTER 2
FOREST REHABILITATION VIA MULTIPLE SPECIES PLANTATIONS (MSPs):THE SILVICULTURAL STUDY

In this chapter I describe the relevance of Karnataka's MSPs to growth studies of tree seedlings in a forest understory environment. Both theoretical and practical aspects of seedling shoot growth beneath a forest canopy are reviewed, emphasizing effects of extended exposure to understory conditions. This leads to the specific focus of this study: the effect of different periods of exposure to understory conditions on shoot growth rates of two tropical tree species. How varying periods of understory exposure might affect seedling shoot growth after release from understory conditions is also discussed. Finally, I present a series of research questions that relate duration of understory exposure, species type, and experimental release from understory conditions to seedling shoot growth rates over a 12 month research period.

Tree Seedlings and the Forest Understory

The forest understory environment presents both opportunities and challenges to young tree seedlings. Short-lived opportunistic light-demanders, longer-lived light-demanders (Schulz 1960), and some primary forest species cannot germinate or survive in an understory environment. Many primary forest

species do, however, benefit from canopy shade during their establishment phase (Bazzaz 1980). Large vapor pressure deficits, desiccating winds, extreme temperatures, and radiation loads are reduced beneath the forest canopy. Understory conditions allow shade-tolerant seedlings to establish root systems that can support further growth of photosynthetic stem tissue. Once established, however, seedling growth rates in the understory inevitably slow as a result of competition from neighboring trees (Marquis 1981, Shukla and Ramakrishnan 1984) and herbaceous vegetation (Krajicek 1975). Canopy thinning studies have yielded a doubling in stem growth rates of seedlings and saplings two to three years after release treatments (Erdmann and Peterson 1972), but may also have the inverse effect of depressing height growth (Erdmann et al. 1975) in favor of diameter growth - depending on the amount of canopy removal.

Removal of canopy trees may also result in seedling stress or even mortality if exposure occurs too abruptly or if seedlings are insufficiently established. This shock effect is often because the ratio of root absorbing surface to transpiring surface (fine root:leaf surface ratio) suitable for shaded conditions does not increase quickly enough to replace shoot transpiration losses (Kramer and Koslowshi 1979) after release. A seedling water deficit develops, causing stomatal closure and a decrease in carbon fixation; the reduced capacity for transpirational cooling can also result in heat stress and death.

Shelterwood and related silvicultural systems are based on the incremental removal of canopy trees to attenuate

environmental stresses on seedlings that occur with instantaneous release. Support for this silvicultural approach comes from Marquis (1982), who found that Allegheny hardwood seedlings originating under shelterwood canopies survived overstory removal better than seedlings from natural closed stands. He also recommended that seedlings in natural stands should be at least three years old and 10 to 15 cm tall to survive after release by clearcutting. Seedling age on shelterwood sites, in contrast, had no effect seedlings survival after canopy removal.

With some notable exceptions, such as *Betula alleghaniensis* in the Great Lakes region and *Tsuga heterophylla* in the Cascade Range of North America (Eyre and Zillgitt 1953), sustained exposure to understory conditions is usually disadvantageous to tree seedlings. Suppressed seedlings suffer increased pest attack and/or fungal decay as they lose vigor (Erdmann 1979). They may also be overtopped by more shade-tolerant species. In Michigan, *Acer saccharum* (sugar maple) outgrew *B. alleghaniensis* (yellow birch) after 23 years of suppression (Eyre and Zillgitt 1953). Enhanced growth of understory seedlings in response to release diminishes with age (Marquis 1982). Even though 16-65 year old birch still responded to release (Erdmann and Peterson 1972), trees less than 16 years old had faster growth rates after release.

Residual effects of prolonged exposure to understory conditions have silvicultural implications. In particular, silviculturists need to know how well understory tree seedlings recover and grow after release from varying periods of growth

suppression. Forest economists explore this question in practical terms when evaluating precommercial thinning operations:

> if precommercially released trees consistently grow larger in average diameter at breast height (DBH) than nonreleased trees, does this diameter increase at an early age result in the released trees maturing at a significantly earlier age than nonreleased trees? If true, this could result in shorter rotations, and with shorter rotations, economic evaluations may become more favorable to applying crop-tree release treatment. (Smith and Lamson 1983:3)

If the effect of duration of suppression on seedling shoot growth rates is known, silviculturists can define appropriate species-based rules for seedling release treatments. This, in turn, would hasten the re-establishment of native hardwood forests on degraded sites - which is the long-term objective of Karnataka foresters in establishing MSPs on minor forest sites.

MSPs offer unique opportunities to investigate the effects of species and duration of understory exposure on shoot growth rates of understory seedlings in tropical forests. Several silvicultural attributes of MSPs make this possible:

1) size-graded seedlings representing more than 20 native species and two naturized nitrogen-fixing species were used to reforest two percent of state forestlands in the research area each year from 1982-1991, totaling 20 million seedlings over 12,000 ha;

2) understory seedlings comprise several known age classes, and were growing beneath MSP canopies for known periods of time;

3) overstory stand conditions are as uniform as plantation silviculture permits (i.e. similar overstory species, grown at similar planting densities, on similar soils,

in the same climatic region), to minimize extraneous variation;

4) canopy tree spacing and size in one, two, and three year old plantations permitted manipulation of canopy openness via canopy tree with ropes;

5) soil conditions and tree spacing permitted 0.60 m deep trenching of at least 3.2 m^2 of ground surface surrounding target seedlings;

6) plantation stands are normally well-protected by the local forestry department from theft, arson, and damage from cattle.

Previous studies have been designed to assess the relative effects of root versus shoot competition on woody plant growth using partitioned release experiments (e.g., Christy 1986, Horn 1985, Putz 1992, Putz and Canham 1992, Shainsky and Radosevich 1986, Strothman 1967, Wilson 1988, Zeide 1980). I know of no studies that have addressed the effects of duration of exposure to competition on subsequent growth rates of released woody perennial species (but see Shukla and Ramakrishnan 1984).

Silvicultural Study Focus

This study assesses how shoot relative growth rates (Shipley 1989) of two species of tropical seedlings change during increasing periods of exposure to understory conditions, and after experimental release from them. Release treatments include soil trenching (T), canopy guying (G), and trenching and guying (T + G) combined. The following questions served to guide this study, and define hypotheses for investigation.

1) Do increasing periods of exposure to understory conditions slow growth rates of the two understory seedling species of interest?

2) Do growth rates of a reputedly suppression/shade-tolerant species stabilize, while growth rates of a reputedly less shade-tolerant species continue to slow with increasing periods of continuous understory exposure?

3) What is the effect of one, two, and three years of continuous understory exposure on within species and between species seedling growth rates in the first year after release from understory conditions?

4) Does belowground competition inhibit growth rates of understory seedlings more than aboveground competition when understory exposure time is held constant?

Question 1) can be addressed by within-species comparisons of seedling shoot growth rates for control treatments in plots of increasing age address. As more numerous, faster-growing, nitrogen-fixing trees progressively occupy growing space above ground and below ground in MSPs, shoot growth rates of understory seedlings are expected to slow, regardless of species. When tree canopies begin to overlap and root systems intermingle, competition for shared space, light, nutrients, and moisture inevitably begins. Slowed shoot growth of understory seedlings, when it does occurs, can serve as a marker of the intensification of resource competition. The search for this horizon of competition can begin in the youngest MSPs - those that are one, two, and three years old. Four year old canopy trees are too large to receive experimental treatments. This study was therefore limited to one, two, and three year old MSPs.

Branches of adjacent seedlings planted at 3 m spacings remained completely separated during the first year of MSP establishment. I assumed that intermingling of root systems was

also limited during this first year. During the second and third years, however, MSP canopies can reach heights of six to seven m and close. Trenching similarly revealed that by the second year, lateral roots of neighboring seedlings intermingle. If, however, understory seedling shoot growth fails to slow during MSPs' second or third year, it may be that growth is merely reallocated - such as to greater shoot extension, at the expense of diameter growth. Comparison of shoot height and root collar stem diameter growth data provided information about allocation of growth in understory seedlings.

Conversely, fast-growing overstory trees may create beneficial growing conditions for young understory seedlings. Increased litter accumulation, nitrogen fixation, and retention of soil moisture provide explanations for such ameliorated conditions. Many local foresters maintain that MSPs enhance survival and early growth of understory seedlings. My observations at several area plantations lacking fast-growing matrix species supported their claim. Sustained or enhanced shoot growth of understory seedlings in this experiment would further substantiate the early beneficial effects of MSPs.

Question 2) can be addressed by between-species comparisons of seedling shoot growth rates for control treatments in plots of increasing age. Shoot growth responses are expected to be species-specific as MSPs age - as mediated by a species' tolerance of understory conditions. For example, shoot growth rates of a reputedly understory/shade-intolerant species should slow as MSP overstory trees mature, while growth of more shade-

tolerant species should vary less or stabilize. Due to its limited time horizon, this study is unable to measure any slowdown in shoot growth of the understory-intolerant species occurring beyond a MSP's third year.

Question 3 can be addressed by within-species and between-species comparisons of seedling shoot growth rates for trench and guy (T+G) release treatments in stands of increasing age. In the first year after experimental release from one, two, and three years in the MSP understory, each species is expected to achieve enhanced shoot growth over that of controls for that species for the same year. Within-species shoot growth is also expected to increase uniformly after release, regardless of understory exposure time. Recovery capacity of young seedlings, particularly understory-tolerant species, should not be altered by understory exposure that varies by only one to three years. Even the less understory-tolerant species should recover uniformly from these small differences in understory exposure time. Most seedlings sustain understory exposures much longer than three years in natural forests, and still respond to growth opportunities provided by the death of overstory trees (Hartshorn 1982). Shoot growth of the less-tolerant species should, however, respond more favorably to release treatment than does the more tolerant species, due to the former's adaptive preference for open, unimpeded growing space.

Question 4) can be addressed by comparison of growth responses to factorial treatments (i.e., control, trench, guy, trench and guy) and one further contrast (NPK fertilization) -

the extent to which aboveground and/or belowground factors inhibit understory seedling shoot growth in MSPs. This factorial experiment was imposed only on the more understory/shade-tolerant species in the oldest (three years) MSPs, assuming that similar results could then be expected for less-tolerant species.

The research area's pronounced wet and dry monsoon climate produces a marked growing season from June to December, followed by a droughty semi-deciduous/dormant season from January to May. Seedlings in forest nurseries grow quickly during the hot, dry months only because irrigation is provided. Year-round canopy openness from nine to 37 percent and abundant sunflecks beneath the oldest MSPs studied lead to the prediction that soil moisture limits understory seedling shoot growth rather than sunlight. Enhanced evapo-transpiration caused by canopy guying (G) should therefore limit seedling shoot growth, not soil trenching (T).

Nearly all MSPs are located on paleustalf soils (FAO World Soils Map 1988) having litter layers that thicken to 3-7 cm by a plantation's third year. Organic matter in the top 10 cm of 12 MSP soils varied from 2.0 to 7.3 percent by soil weight, and averaged 3.1 percent (Walkley-Black dichromate methodology, IFAS Analytical Research Laboratory, University of Florida). All macro and micro-nutrients were found to be in sufficient supply for plant growth. The NPK treatment is therefore not expected to increase the shoot growth of understory seedlings.

CHAPTER 3
SILVICULTURAL STUDY: SITE SELECTION AND IMPLEMENTATION

In this chapter I describe the silvicultural study. Formulation and implementation of my research plan evolved from a 1990 tour of northwestern Karnataka's Sirsi Forest Division. Experimental species and research sites selected for execution of the plan are discussed. I then describe the process of experimental plant selection, imposition of experimental treatments, plot maintenance during the 1991-92 research year, and final plant harvest and processing procedures. Finally, I describe calibration harvests that were used to estimate initial shoot dry weights of experimental plants that were not destructively harvested until the end of the year-long experiment.

Research Area Selection

I visited 12 Multiple Species Plantation (MSP) plots during a January 1990 tour of the Sirsi Forest Division. Increases in shoot height and root collar basal area were easily distinguished among native tree seedlings that had been growing one, two, or three years within MSPs. These observations were discussed with local foresters, and their opinions about the relative shade or understory tolerance of many native tree species were noted. There was agreement that all species achieve maximum growth when

growing in forest gaps or openings, but that some species tolerate shade better than others. The most frequently planted species were classified as either "shade tolerant" or "shade intolerant". Shade-tolerant species included *Lagerstroemia lanceolata* (nundi), *Terminalia paniculata*, and *Dalbergia latifolia*. *Terminalia tomentosa* (mutti) and *Pterocarpus marsupium* were considered more shade-intolerant species.

Proposed experimental treatments of tree seedlings in MSP understories were tested using canopy guying and soil trenching techniques. Guying involved pulling back and securing all canopy trees that overtopped a target tree. This procedure was tested in a three-year old MSP and found to be feasible. To test proposed soil trenching techniques, two-year old *L. lanceolata* and *T. tomentosa* seedlings were transplanted into 60 X 60 X 60 cm pits in the Kalve Nursery of Sirsi Forest Division. The sides of these pits were lined with 30 guage plastic sheeting (Biradar Plastics, Malmaddi, Dharwad 580 007 India). Excavation of these trenches 17 months later was done to assess possible confounding effects of plastic root barriers on seedling root growth in planned experimental trenching treatments. All five *T. tomentosa* and five *L. lanceolata* seedlings survived this soil trenching pre-test. Both species more than tripled in stem height, indicating that changes in shoot growth would be distinguishable after a 12 month study. Excavation of roots indicated that lateral roots of four seedlings had extended to the plastic barriers and were growing along them. The distance between plastic barriers and seedling bases was therefore increased to

one m, in experimental trenching treatments. Excavation also showed that the 30 guage plastic used as root barriers around the seedlings had partially deteriorated after 17 months under ground. I therefore chose to use thicker, 60 guage plastic sheeting in all trenching treatments.

Trenching and guying preliminary studies convinced me that these treatments could be successfully imposed on one, two, and three year-old MSP plots available in the Sirsi Forest Division. There was insufficient time during this initial visit to select specific tree species or MSP plots for the field study.

Research Site Selection

In early May 1991, Sirsi Forest Division officers provided information about all plantation plots within their five jurisdictional forest ranges. These plots ranged in size from five to 90 ha, with an average area of 25 ha. It soon became clear that plots planted prior to 1987 could not be considered for this study. From 1982 to 1986 MSP silviculture had evolved by trial and error, and was not consistent in its application. Plots were few and scattered, while the types of species used and their planting densities were not uniform. Karnataka Forest Department Officers S.S. Hegde and S.D. Sumshekar tallied all 315 forest division plantation plots planted from 1987 through 1991. Numbers of new plots planted each year from 1987-1991 appear in Table 3-1.

Table 3-1. Sirsi Forest Division plantations: number of plantations planted from 1987-1991

YEAR PLANTED	1987	1988	1989	1990	1991
PLOTS PLANTED	72	40	73	80	50

Two hundred three of these stands were located in minor forest areas, 106 stands were in reserve forests, and six stands were in forests where local spice garden owners have historical tree lopping privileges - so-called *soppina betta* forests. Two hundred seventy-nine of these stands are true MSPs, while 36 stands were planted with either *Bambusa* spp. (bamboo), *Santalam album* (sandalwood), *Acacia auriculiformis* (acacia), *Casuarina equisetifolia* (Australian pine), or a limited number of native species.

All 279 MSP stands were considered for their suitability as experimental plots. Most were undesirable for the purposes of this research due to one or more of the following: individual stands were isolated from other MSPs; seedling density was too low, or seedling mortality was too great; locally abundant species of seedings were not commonly found in other MSPs; faster-growing canopy species were uncommon or irregularly spaced; residual trees with spreading canopies were too abundant; micro-climatic irregularities of slope, aspect, or soil rendered plots atypical; or, tree seedlings were sometimes damaged by excessive cattle and/or human disturbance.

From a candidate list of five geographical areas or blocks, four were chosen - Siddupur, Hunsekopp, Aksal, and Heggekopp (see Figure 3-1). Hunsekopp and Aksal blocks are west and north of

Sirsi Town, respectively. Siddapur and Heggekopp blocks are both south of Siddapur Town. The fifth, Hulekal block contained too many large residual trees for inclusion and was rejected. The four acceptable blocks had similar seedling spacing in intra-block plots (two or three meters), and contained a chronologic suite of MSP plots planted during 1988, 1989, and 1990 (see Table 3-2). The youngest (i.e., most recently planted) series of plots (1988-90) was chosen for study in an attempt to track the onset of slowed shoot growth from the earliest possible moment, seedling outplanting from nurseries.

Table 3-2. Local names of 1988-91 research plots located within each of four research blocks

Date Planted	SIDDAPUR	HUNSEKOPP	AKSAL	HEGGEKOPP
1988	MUGDUR	HUNSEKOPP	PUTANMANE	MUSWALLI
1989	PADWANBAIL	HUNSEKOPP	AKSAL	HEGGEKOPP
1990	NAGARBAWI	YECHADI	ANDALLI	HEGGEKOPP

Area reconnaissance also indicated that no other three-year interval provided more than three suitable plots (i.e. one experimental block) for study. Trees in plots older than three years were often too large to easily permit the canopy guying and soil trenching treatments employed in this study.

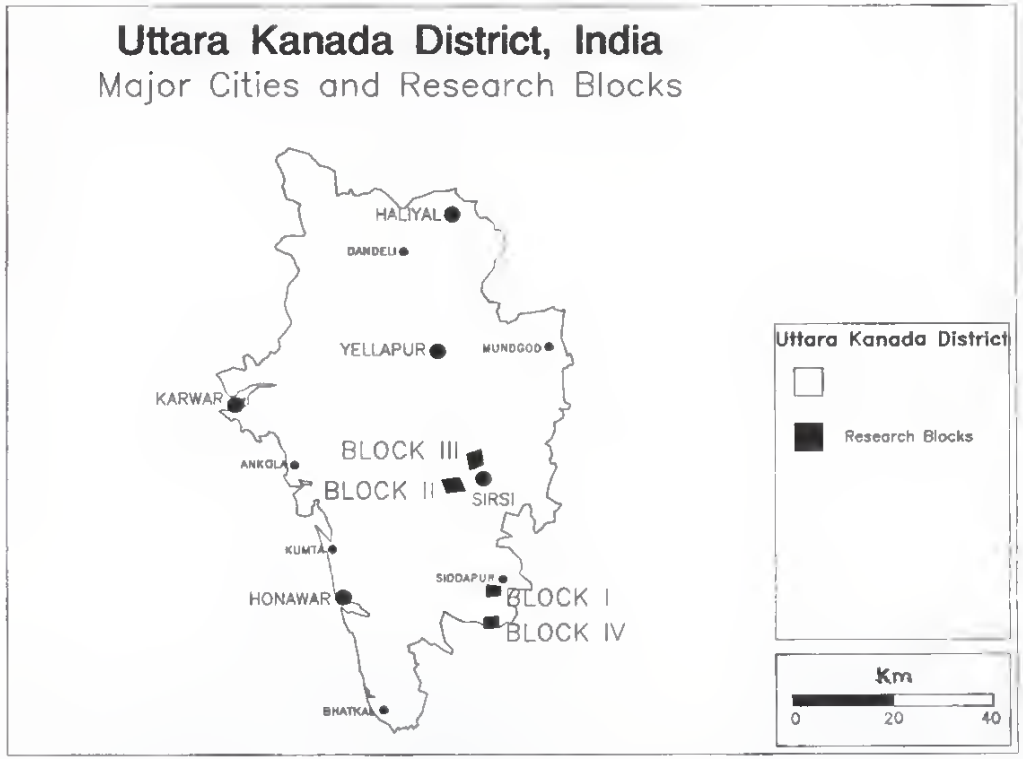


Figure 3-1. Location of research blocks and Uttara Kanada cities
Source: Karnataka Forest Department, Maps Division, Aranya Bhavan, Bangalore

Each of the age-specific plots contained numerous individuals of *L. lanceolata* and *T. tomentosa*. These two native species were chosen for detailed study because the former is known locally to be relatively shade tolerant, while the latter is considered shade intolerant, and because an abundance of outplantings of these two species was found in all experimental blocks and plots. Working with two species of varying shade/understory tolerance allows for a range of potential seedling shoot growth response to a developing plantation environment.

Silvicultural Experiment Design

This study was designed to investigate the impact of MSP plantation age and associated temporal effects of plantation development on shoot growth rates of understory seedlings. The experimental design appears in Figure 3-2. Each of the four geographical blocks contained at least one plot that had received MSP treatment in each of the following years: 1988, 1989, and 1990. The numbers and kinds of experimental treatments assigned to experimental seedlings in 1988 plots, and in both 1989 and 1990 plots is shown in Tables 3-3 and 3-4 respectively.

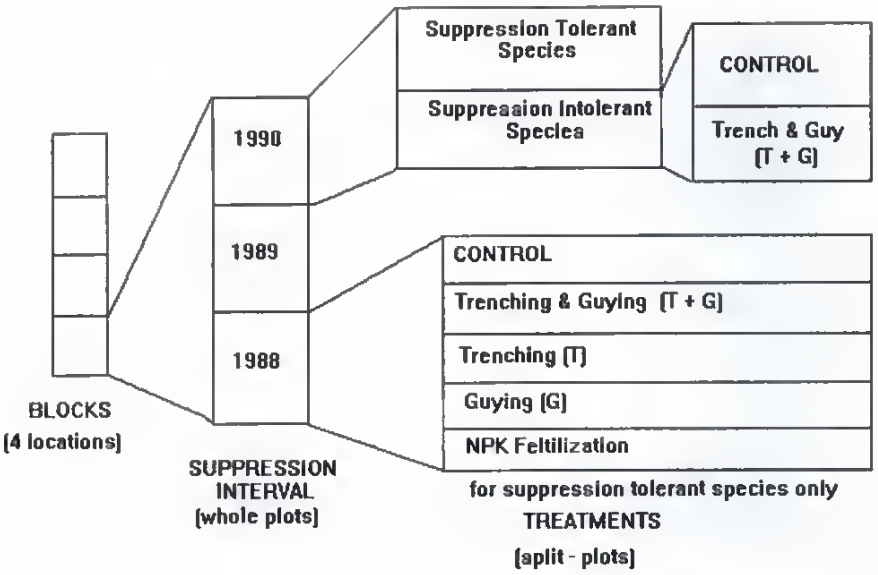


Figure 3-2. Silviculture experiment design: blocks, whole plots, and split plots

Table 3-3. Number of treatments assigned to experimental units in 1988 MSP plots, by species

	CONTROL	TRENCH	GUY	TRENCH & GUY	FERTILIZATION
Lagerstroemia lanceolata	4	4	4	4	4
Terminalia tomentosa	4	0	0	4	0

Table 3-4. Number of treatments assigned to experimental units in 1989 and 1990 MSP plots, by species

	CONTROL	TRENCH & GUY
Lagerstroemia lanceolata	4	4
Terminalia tomentosa	4	4

Only *L. lanceolata* received all four factorial treatments and the fertilization contrast - and only in the oldest, 1988 MSP plots (see Table 3-3). These oldest plots under study offered the greatest potential for detection of slowed seedling shoot growth resulting from resource competition, given that physical crowding above and below ground increases as plantations mature. For this reason I decided to impose all treatment levels on the 1988 plots, and to do this for the reputedly more shade/understory-tolerant species, *L. lanceolata*. If slowed growth could be detected for the more tolerant species, then *L. lanceolata*'s response to crowding should apply to other, less-tolerant species. The reputedly less-tolerant *T. tomentosa* received only the combined soil trenching-canopy guying and control treatments in the 1988 plots.

The canopy guying by soil trenching factorial design explores the contribution of both aboveground and belowground factors to changes in seedling shoot growth for the year after imposition of treatments. The fertilization treatment tests whether soil macro-nutrients or soil moisture is more limiting to seedling shoot growth in MSPs during the year after experimental treatment. The combined canopy guying and soil trenching treatment (see Figure 3-3) mimics a release event that seedlings normally experience as a result of plantation thinning operations. Seedling shoot growth was monitored during the year following experimental release.

In the 1989 and 1990 plots, both *L. lanceolata* and *T. tomentosa* received only the combined soil trenching-canopy guying

and the control treatments, due to the time and expense of imposing these treatments. The five weeks available to initiate the experiment prior to the early June arrival of the monsoon were also too short to establish all 12 experimental plots. Plots in Aksal and Heggekopp blocks had to be established during the monsoon rains of June and July. Soil trenching operations became more arduous under wet soil conditions. Ultimately, the experimental design was replicated over all four blocks, comprising 60 experimental seedlings per block - for a total of 240 experimental units.

Plant Selection and Imposition of Experimental Treatments

Selection of individual experimental plants and implementation of treatments began in early May of 1991. I initially walked through the 1988, 1989, and 1990 plots in each of the four blocks to assess spatial uniformity of outplanted *L. lanceolata* and *T. tomentosa* seedlings. Some plots contained uniform distributions of *L. lanceolata* and *T. tomentosa* throughout, while others had few or none of these two species within their boundaries. Areas having sufficient *L. lanceolata* and *T. tomentosa* seedlings were entered and a random compass bearing was followed for a random distance between 15 and 20 m. Making a right-angle turn at this point, I began to scan in front and three m on either side of my path for *L. lanceolata* and *T. tomentosa* seedlings.

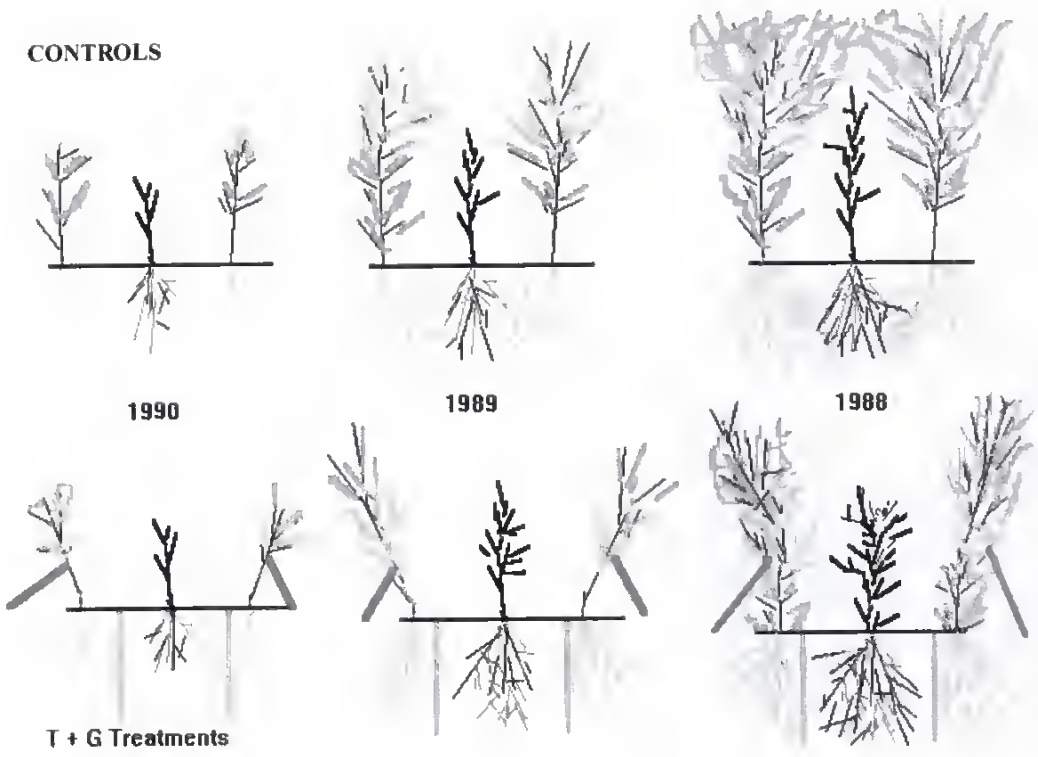


Figure 3-3. Comparison of control and combined soil trenching-canopy guying treatments applied in 1991 to one, two, and three year old plantations

Each candidate seedling encountered was inspected for signs of damage, disease, multiple stems, or the presence of vegetation within one m of its base. Individuals having none of these deficiencies were flagged for later measurement and treatment. When coming within 20 m of a plot edge, I made a second right-angle turn and walked six to seven meters before making a third right-angle turn, and then continued the seedling scanning procedure.

After I marked a sufficient number of candidate seedlings in a particular plot, I measured the height and root collar diameter of each seedling. When necessary, soil was cleared from around the base of a seedling to permit two root collar diameter

measurements using calipers, the second measurement being at a right angle to the first. Length of the primary stem was recorded from the root collar to the apical bud. The species of the seedling and its general condition were recorded. Each individual was then marked using a labeled laundry tag tied to a length of string, and attached to the main stem just above the point of diameter measurement. A second labeled tag was attached to each individual midway along its stem to insure future identification. Each individual's location was marked on a detailed plot map. Canopy openness was estimated using a hemispherical densiometer (Lemmon 1956), averaging measurements made above each seedling's main stem at 1.2 m above ground, while facing in each of the four cardinal directions. Soil temperature was measured 5 cm and 15 cm below the surface during midday heat, using an analog soil thermometer.

Experimental treatments were then assigned at random to the marked seedlings in each plot using a random number table. The canopy had not yet closed in the most recently planted 1990 plots, and little or no guying of matrix *Acacia* and/or *Casuarina* crowns was therefore required until six months later, after the monsoon. Smaller plantation trees could usually be held under tension while being guyed to neighboring tree limbs or stems. Canopy openness in 1989 plots varied from 50 percent to 90 percent, and could easily be increased from 85 percent to 90 percent openness by guying. Guying became progressively more difficult as plot age increased. Three year old *Acacia* and *Casuarina* trees in 1988 plantations often had basal diameters of

13 cm or more, and heights of six to seven m. Here canopy openness ranged from 9 to 37 percent, and could be increased with guying to only 45 percent to 50 percent openness. To bend these larger individuals down for guying required climbing more than half way up them, allowing one's body weight to slowly bow tree stems downwards. On more than a dozen occasions the snapping of tree crowns under my own body weight caused falls of three to four meters. Wearing a motorcycle helmet increased my confidence, and perhaps protection, when crowns snapped. Guyed treatments were checked and retied during each of the five maintenance visits made to every plot during the one year experiment. Reguying usually increased canopy openness a further 15 percent by the time the experiment was concluded.

Soil trenching was the most difficult aspect of initiating the silvicultural study. Each perimeter trench was hand-dug 50-60 cm deep, 25 cm wide, 7.2 m in circumference, and positioned 1.0 - 1.1 m away from the stem of the experimental seedling, at its center. Under optimal conditions, four such pits could be dug, lined with 60 guage black plastic sheeting (three year durability guarantee from Biradar Plastics, Malmaddi, Dharwad 580 007 India), and back-filled during a full day of digging. One hundred twelve pits were dug in this study, taking more than a month for myself and two assistants to complete. While digging I noted that most rooting activity occurred in the upper 35 cm of the soil profile, including most large lateral roots. Roots smaller than 0.5 cm diameter were sometimes observed to extend below a depth of 60 cm, but even these were uncommon. For this

reason I concluded that soil trenching would be an effective experimental method to reduce belowground competition for experimental plants, although it did not prevent competition deeper in the soil profile. Some target seedling roots were necassarily cut during trenching in the oldest, 1988 plots, but damage was minimal to target seedling roots in 1989 and 1990 plots.

NPK fertilizer was added twice to selected 1988 *L. lanceolata* seedlings - first in June and then again in October of 1991. One hundred grams of Jai Kisaan's "Sampurna" 19:19:19 NPK particle mix (NO_3 19%, P_2O_5 19%, K_2O 19%, Zuari Agrochemicals, Ltd., Goa, India), were poured into three 30 cm deep, 2 cm wide soil auger holes, drilled at a distance of 40 cm from each experimental seedling stem. This NPK treatment was a planned contrast with the trenching treatment, also imposed on 1988 *L. lanceolata* seedlings.

Plot Maintenance

I visited all experimental plants five times during the research year to perform plot maintenance and to measure seedling growth. Maintenance duties included: canopy re-guying operations; clearing plant bases to permit remeasurement of root collar diameters; and, relabeling individuals that had become difficult to identify.

The half-way mark of the research year was December 1991 - the end of the rainy season. I took advantage of this natural break in season to record shoot height and root collar diameter

growth of all experimental seedlings. These data allow comparison of understory seedling shoot growth for the wet (June-December) and dry (January-May) portions of the 1991-92 research year. I expect that most seedling shoot growth would occur during the wet monsoon, and that dry season conditions result in slow or even negative growth, due to elevated evapotranspiration and associated stem shrinkage.

Plant Harvesting, Processing and Measurement

Destructive harvest of all experimental plants occurred from May 25 - June 20, 1992. The 1992 monsoon arrived on June 7 and slowed harvest of Aksal and Heggekopp blocks. I recorded shoot height, root collar diameter, and shoot condition for each surviving experimental plant. I also measured canopy openness, and soil temperatures 5 cm and 15 cm below the surface.

To estimate shoot biomass, seedlings were clipped at the point of root collar measurement, cut into 25-30 cm lengths, sealed in marked envelopes, and transported to my house for further processing. There shoot fresh weights were recorded using a DW 2000 g No. 015 IPA electronic top loading balance (IPA Services, Peenya Industrial Estate, Bangalore 560 058 India), prior to drying at 70° C (Pearcy 1989) in a 'Biochem' hot air oven (Universal Biochemicals, Sathya Sayee Nagar, Madurai 625 003, India) from two to six days - until dry weights stabilized. Drying time was a function of shoot diameter, thicker individuals requiring longer to dry to a constant weight.

Finally, 10 individuals each of *L. lanceolata* and *T. tomentosa* were ashed, and the ash weighed to determine average ash content of each species.

Calibration Estimates Requiring Destructive Measurements

Calibration data both species were obtained in the following manner. Non-destructive measurements (i.e., shoot height and root collar basal area) of all experimental plants at the May-June 1991 start of the study was complemented by destructive measurement of 23 randomly-selected seedlings - outplanted into MSPs a year earlier, in June 1990. From these 11 *L. lanceolata* and 12 *T. tomentosa* individuals shoot dry weight estimates were calculated for 1990 *L. lanceolata* and *T. tomentosa* experimental seedlings using root collar basal area regressions. These 23 seedlings were used because my 1990 experimental seedlings could not be destructively measured at the study's outset. When the study concluded in June 1992, destructive measurements of all 1990 experimental seedlings provided shoot dryweight estimates for experimental seedlings that had already been outplanted for two years when the study began in June 1991 (i.e. my 1989 experimental seedlings). Similarly, destructive measurements of all 1989 experimental seedlings provided shoot dry weight estimates for experimental seedlings that had been outplanted three years prior to the start of the study (i.e. my 1988 experimental seedlings) (see Figure 3-4).

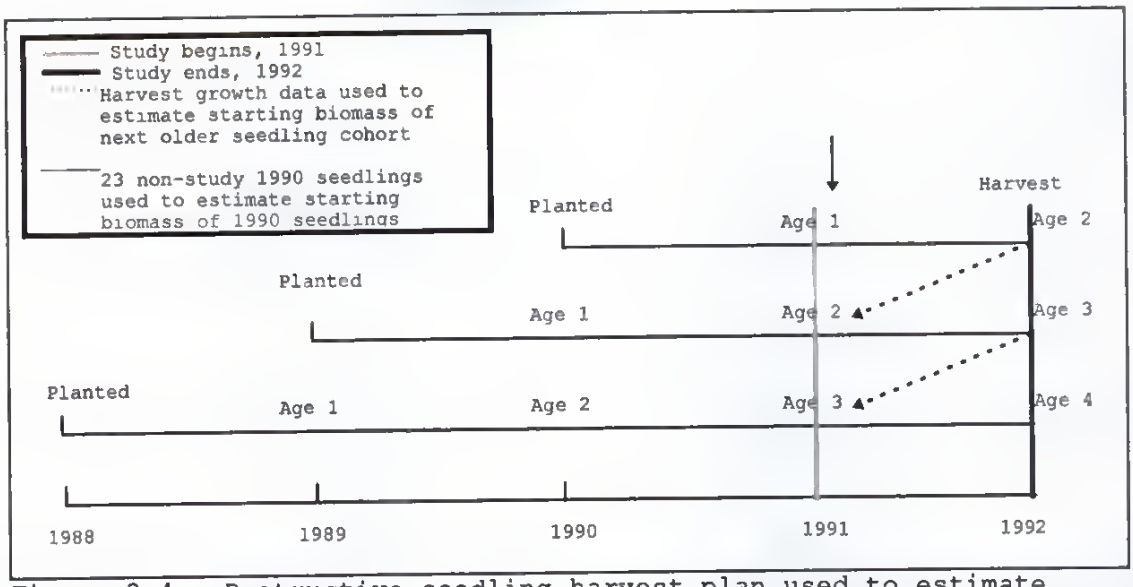


Figure 3-4. Destructive seedling harvest plan used to estimate shoot biomass of one, two, and three year-old seedlings at the start of the 1991-92 study

This strategy of using growth data of younger seedlings collected at the end of the experiment, to estimate initial dry weights of the next older cohort of seedlings at the start of the experiment accomplished two objectives. It insured that calibration measurements were derived from seedlings found growing within the study's experimental blocks, where site conditions were most nearly similar to those of other experimental seedlings. It also minimized the destructive impact of this study on seedling regeneration within the research area.

Table 3-5 contains the calibration equations used to estimate shoot dry weights at the June 1991 start of the experiment for all three seedling age cohorts. Root collar basal area was found to provide better estimates of shoot dry weight than shoot height, and was therefore used in deriving the equations in Table 3-5.

Table 3-5. Seedling root collar basal area (cm^2) regressions used to estimate *Lagerstroemia lanceolata* and *Terminalia tomentosa* shoot dry weights (g) at the start of the experiment

	1990	1989	1988
L. lanceolata	$y = -10.727 + .325(x)$ $R^2 = .934$ se = 2.02, n = 12	$y = -2.118 + .207(x)$ $R^2 = .743$ se = 4.94, n = 32	$y = -219.64 + .791(x)$ $R^2 = .970$ se = 26.85, n = 28
T. tomentosa	$y = -11.070 + .419(x)$ $R^2 = .955$ se = 4.49, n = 11	$y = -9.692 + .199(x)$ $R^2 = .768$ se = 4.21, n = 28	$y = -50.574 + .335(x)$ $R^2 = .811$ se = 9.27, n = 28

y = shoot dry weight estimate
x = root collar basal area
se = standard error of slope coefficients
n = sample size

Shoot dry weight calibration estimates for June 1991, when the yearlong study began, were used to calculate shoot relative growth rates (RGRs) as described by Evans (1972) and Hunt (1978):

$$\text{RGR (grams gram}^{-1}\text{ interval}^{-1}) = \frac{\log_e H_2 - \log_e H_1}{T_2 - T_1}$$

where,

H_1 = shoot height (cm), root collar basal area (mm^2), or oven-dried shoot biomass (g) at the beginning of the experimental interval

H_2 = shoot height (cm), root collar basal area (mm^2), or oven-dried shoot biomass (g) at the end of the experimental interval

$T_2 - T_1$ = experimental measurement interval.

RGR, an index of efficiency of plants as producers of new material (Hunt 1978), permits comparisons of growth for plants of unequal size. Here it is equivalent to the slope of the natural logarithm of shoot growth (H) plotted against time (T). This study compares these RGRs with respect to species, treatment, and MSP age. RGR comparisons of shoot dry weights were made for the 12 month study period. Shoot height and root collar basal area RGRs were compared over wet (June-December) and dry (January-May) season periods, and did not require destructive sampling or calibration. Testing for differences in RGRs of seedling shoot height, root collar basal area, and seedling shoot dry weight were done using PC SAS, Version 3.0 (1994) and the SAS General Linear Models Procedure (Littell et al. 1994). These results are presented with other experimental results in Chapter 4.

CHAPTER 4
SILVICULTURAL STUDY RESULTS AND DISCUSSION

INTRODUCTION

This chapter presents results of the shoot growth rate study conducted on seedlings of native trees growing within Multiple Species Plantation (MSP) plots. Ancillary information collected for shoot growth seasonality, damage to experimental plants, and abiotic conditions beneath MSPs are also presented and discussed. The chapter concludes by summarizing the potential role of MSPs in rehabilitation of degraded tropical forests. MSPs represent a workable ecological response to forest degradation, yet they may also contribute to the impoverishment of local, forest-dependent communities. Both reduced biodiversity and tenure/usufruct explanations for local grievances about MSPs are presented as an introduction to the second portion of this research - the community forest resource use study.

Seedling Growth Rates During Monsoon versus Dry Seasons

Measurement of changes in shoot extension and root collar area growth, as well as estimates of shoot dry weight increment were calculated for both the wet monsoon (June-December) and dry (January-May) seasons. Comparison of these three growth parameters for the two periods illustrates that nearly all shoot growth occurred during the wet monsoon (see Table 4-1).

Table 4-1. Percentage of annual seedling shoot growth occurring during monsoon versus dry season, n=174

Season	**Shoot Extension**	**Root Collar Area Growth**	**Shoot Dry Weight Increment (based on calibration estimates)**
Monsoon (Jun-Dec)	96 percent	100 percent	100 percent
Dry (Jan-May)	4 percent	net negative growth	net negative growth

Dry season conditions resulted in negative root collar area growth and negative shoot dry weight increment estimates in 73 percent and 60 percent of all experimental plants, respectively. This result is apparently due to cross-sectional stem shrinkage caused by excess evapotranspiration. June-December monsoon plant growth data are, therefore, more meaningful in comparing shoot growth rates during the one-year research study. Because of the January-May stem shrinkage, all plant growth results presented below are derived from the seven month monsoon growth period.

Experimental Plant Damage and Measurement Problems

Seventy of 244 (32 percent) experimental trees were damaged or died during the one year research period, while 174 trees (68 percent) were not damaged. Fifty-three of the damaged trees were browsed by domestic animals, 10 were hacked by villagers while collecting fodder, 5 were uprooted by porcupines, and two died of

unknown causes. Tree damage events were recorded when observed, and all affected trees were thereafter excluded from further shoot growth calculations. Fifty-two of the 70 (74 percent) damaged trees were located in the Aksal and Heggekopp blocks. These two blocks were physically closer to hamlets than the Siddapur and Hunsekopp blocks, accounting for more frequent tree damage.

Aksal and Heggekopp blocks also yielded eight of nine net negative shoot dry weight treatment means for all blocks during the study. Eight of 24 (33 percent) shoot dry weight treatment means within these two blocks were net negative. I was unable to establish Aksal and Heggekopp blocks before the 1991 monsoon arrived, thus measuring shoots after they had already begun to expand with monsoon water. Aksal and Heggekopp blocks were subsequently harvested for final measurement just before the monsoon returned in 1992, when stems were shrunken to their maximum extent. This timing inconsistency in shoot measurements in Aksal and Heggekopp blocks accounts for the net negative growth recorded there. Beginning and year-end shoot weight increment data collected from Aksal and Heggekopp blocks are, therefore, not comparable to Siddapur and Hunsekopp block growth data, which were properly recorded before the monsoon arrived in both 1991 and 1992. Because of this temporal/seasonal disparity in the collection of growth data, frequent net negative shoot dry weight increment estimates, and greater incidence of tree damage, all shoot dry weight increment estimates derived from Aksal and

Heggekopp blocks was excluded from shoot dry weight RGR estimates.

Shoot and Root Collar Relative Growth Rate (RGR) Results

Shoot extension in response to increasing periods of understory exposure was species mediated (see Figure 4-1). *Lagerstroemia lanceolata* shoots grew faster than *T. tomentosa* shoots during the first two years of understory exposure, but then slowed dramatically during year three ($F = 16.0$, $p < 0.0002$, $n = 77$). Though the more understory tolerant species, *L. lanceolata*'s faster shoot growth was ultimately curtailed by the closing canopy in three year old MSPs. *Terminalia tomentosa* shoot growth was slower, but sustained during the experiment (see Figure 4-1). *Terminalia tomentosa* seedlings demonstrate that even more understory intolerant species are capable of sustaining themselves beneath a forest canopy when young.

Root collar area growth rates of both of *T. tomentosa* and *L. lanceolata* progressively decreased with increasing exposure to understory conditions ($F = 53.5$, $p < 0.0001$, $n = 77$; see Figure 4-2). Species-based differences in root collar growth rates were not significant.

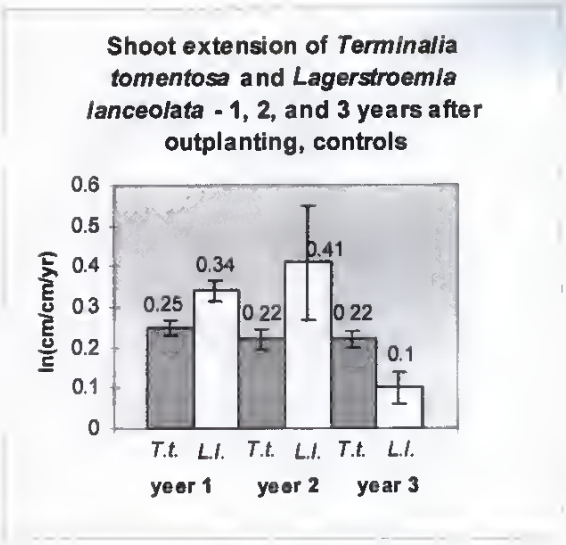


Figure 4-1. Shoot extension comparison of *Terminalia tomentosa* and *Lagerstroemia lanceolata* - one, two, and three years after outplanting into MSPs

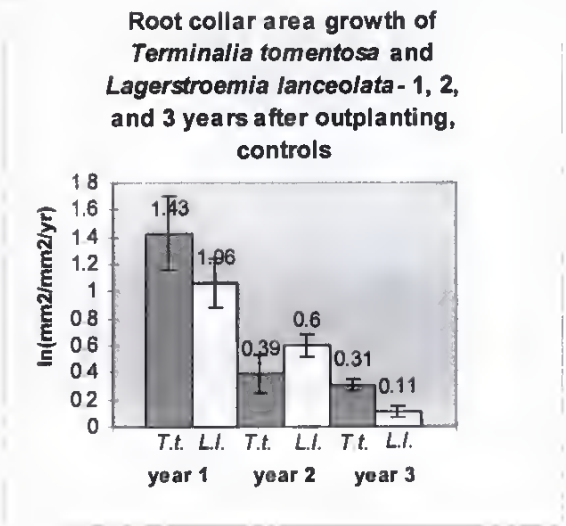


Figure 4-2. Root collar area growth comparison of *Terminalia tomentosa* and *Lagerstroemia lanceolata* - one, two, and three years after outplanting into MSPs

Shoot dry weight increments for both tree species apparently increases with increasing exposure to understory conditions, but this was due to block * year interaction ($F = 9.13$, $p < 0.0003$, $n = 77$), rather than the effect of number of years of understory exposure (see Figure 4-3).

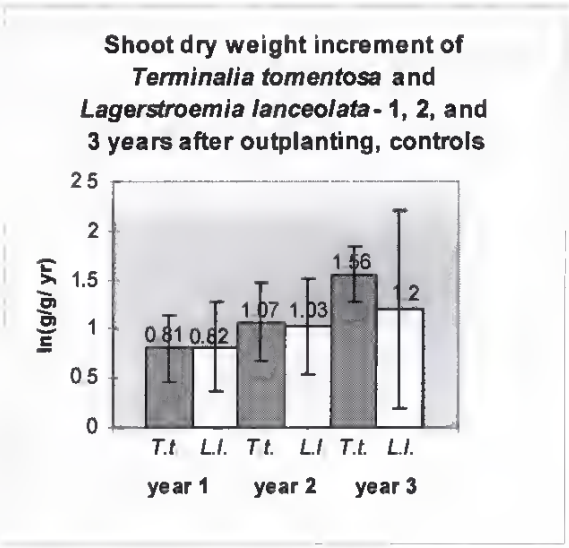


Figure 4-3. Shoot dry weight increment comparison of *Terminalia tomentosa* and *Lagerstroemia lanceolata* - one, two, and three years after outplanting into MSPs

The next six graphs represent the effects of one, two, and three years of continuous understory exposure on experimental plants' shoot growth rates in the first year after release from understory conditions. Figure 4-4 indicates that experimental release of *L. lanceolata* produced significant post-release shoot extension after one and three years of understory exposure ($F = 5.3$, $p < 0.025$, $n = 74$). The effect of release after two years of understory exposure is inconclusive.

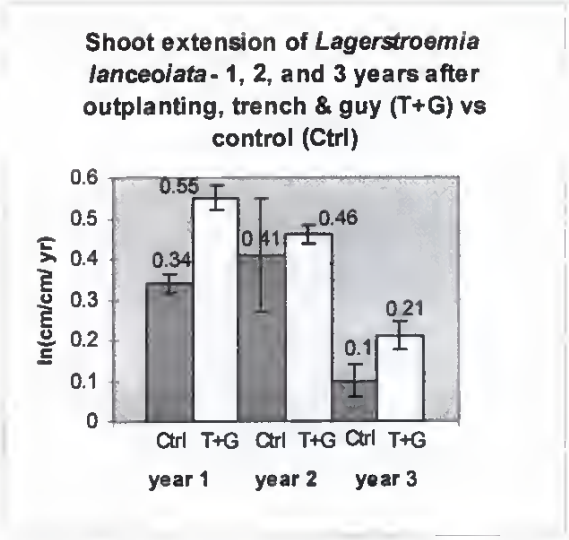


Figure 4-4. Shoot extension of *Lagerstroemia lanceolata* - one, two, and three years after outplanting into MSPs, Trench & Guy (T + G) vs Control (Ctrl)

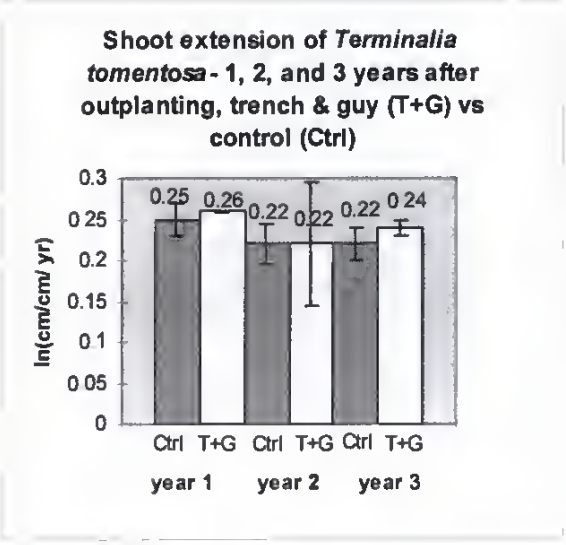


Figure 4-5. Shoot extension of *Terminalia tomentosa* - one, two, and three years after outplanting into MSPs, Trench & Guy (T + G) vs Control (Ctrl)

Experimental release of *T. tomentosa* trees from understory conditions produced uniform post-release shoot growth rates (see Figure 4-5).

Root collar growth rates also increased for *T. tomentosa* seedlings after they were relaesed from two and three years of understory exposure ($F = 3.4$, $p < 0.068$, $n = 77$; see Figure 4-6), when compared to controls. These increases occurred within the context of slowing root collar area growth rates for both release and control treatments. Release therefore mitigated a general slowing of shoot growth among all *T. tomentosa* trees. Figure 4-7 demonstrates a more pronounced mitigation of slowing root collar area growth for released *L. lanceolata* trees, regardless of understory exposure time ($F = 7.6$, $p < 0.008$, $n = 74$).

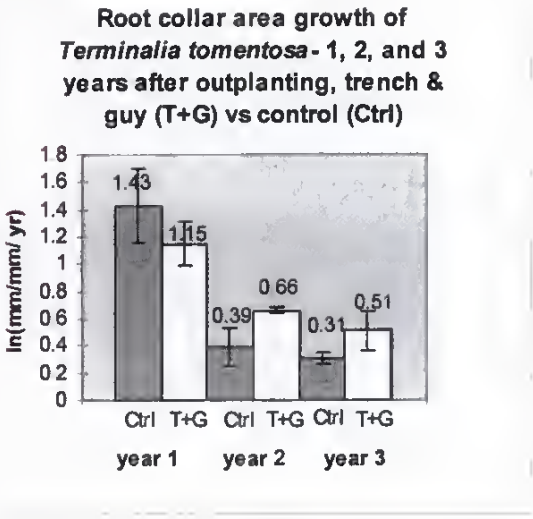


Figure 4-6. Root collar area growth of *Terminalia tomentosa* - one, two, and three years after outplanting into MSPs, Trench & Guy (T + G) vs Control (Ctrl)

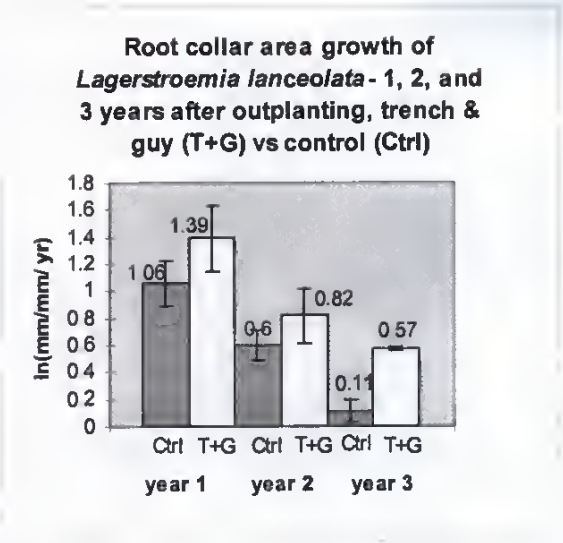


Figure 4-7. Root collar area growth of *Lagerstroemia lanceolata* - one, two, and three years after outplanting into MSPs, Trench & Guy (T + G) vs Control (Ctrl)

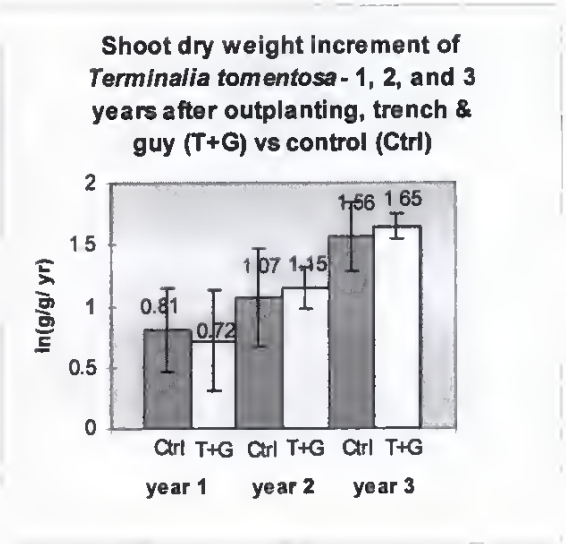


Figure 4-8. Shoot dry weight increment of *Terminalia tomentosa* - one, two, and three years after outplanting into MSPs, Trench & Guy (T + G) vs Control (Ctrl)

Post-release increments of shoot dry weights were not significant, when compared to controls, for either *T. tomentosa*

(see Figure 4-8) or *L. lanceolata* (see Figure 4-9), regardless of prior duration of understory exposure. Figures 4-8 and 4-9 suggest, however, that post-release shoot weight increments did not decrease with increasing exposure to understory conditions.

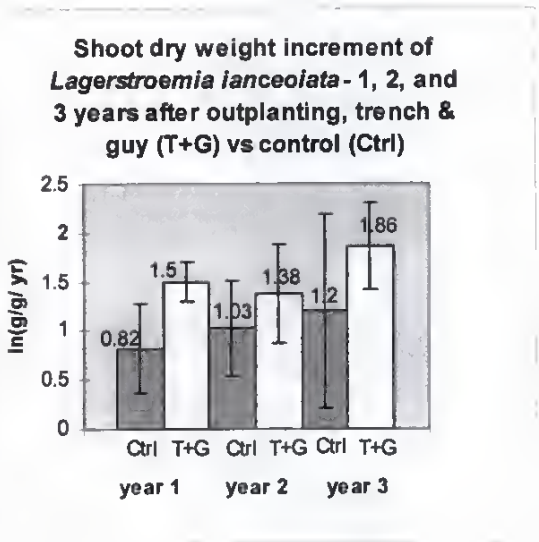


Figure 4-9. Shoot dry weight increment of *Lagerstroemia lanceolata* - one, two, and three years after outplanting into MSPs, Trench & Guy (T + G) vs Control (Ctrl)

The final three graphs compare the growth inhibition effects of belowground and aboveground competition on *L. lanceolata* plants' shoot growth rates after three years of understory exposure. They also compare trench (T) to fertilization (NPK) treatments to identify whether soil moisture or soil nutrients more limit shoot growth rates. Figure 4-10 shows that while all four imposed treatments resulted in increased shoot extension relative to controls, differences between the applied treatments were not significant statistically ($F = 2.2$, $p < 0.102$, $n = 31$). Similar, non-significant results were obtained for root collar

area (see Figure 4-11) and shoot dry weight increment (see Figure 4-12) when comparing the four non-control treatments.

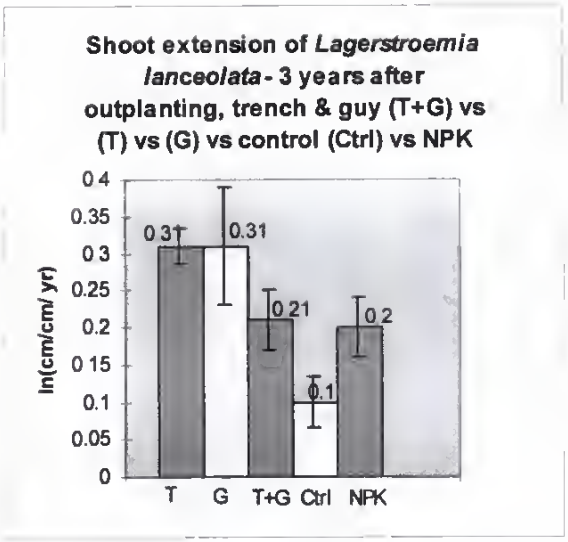


Figure 4-10. Shoot extension of Lagerstroemia lanceolata - three years after outplanting, trench and guy vs trench vs guy vs control vs NPK treatments)

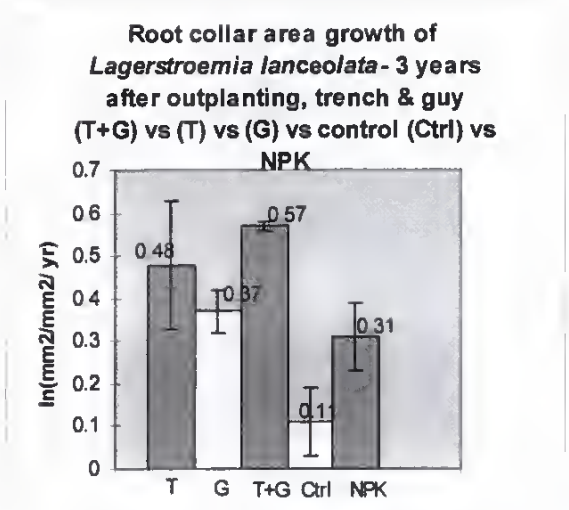


Figure 4-11. Root collar area growth of Lagerstroemia lanceolata - three years after outplanting, trench and guy vs trench vs guy vs control vs NPK treatments

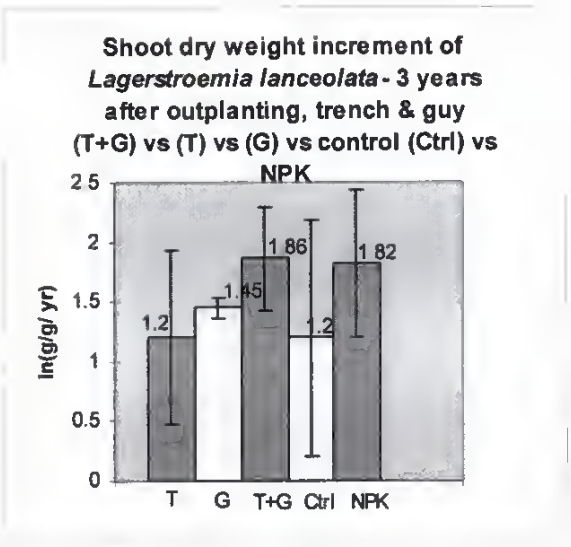


Figure 4-12. Shoot dry weight increment of Lagerstroemia lanceolata - three years after outplanting, trench and guy vs trench vs guy vs control vs NPK treatments

Discussion: Ecological Potential of MSPs

The MSP understory environment promotes shoot growth of understory seedlings during their first two years after outplanting. This growth occurred almost entirely during the June-December wet season. In contrast, shoots often contracted in cross-sectional area and dry weight during the January-May dry season.

Abiotic changes beneath MSPs that extend understory seedlings' effective growing season further into the dry season would improve their growth performance. Lower soil temperatures, enhanced and prolonged retention of soil moisture, increased accumulation of leaf litter, and reduced insolation may all improve the MSP understory for seedling growth. For example, noon temperatures 15 cm below the soil surface in May were cooler beneath a three year-old MSP than beneath a neighboring

plantation with open-grown seedlings of the same age (29.5° C vs 35.3 ° C). Repeated dry season measurements of these abiotic factors could could test for potential increases in the effective growing season provided by the MSP environment.

Table 4-2. Comparative shoot and root collar growth of 16 trees, grown with and without matrix trees in multiple species plantations (MSPs), n=16

Species	**Trees Grown With Matrix Trees**	**Trees Grown Without Matrix Trees**
Terminalia tomentosa shoot extension (cm/yr)	26.2	31.8
Lagerstroemis lanceolata shoot extension (cm/yr)	124.5	56.8
both species (cm/yr)	80.8	44.3
Terminalia tomentosa root collar area (mm2/yr)	2.1	9.1
Lagerstroemis lanceolata root collar area (mm2/yr)	10.1	9.0
both species (mm2/yr)	4.8	9.1

The growth form of understory seedlings also improves with the presence of fast-growing, nitrogen-fixing matrix species in MSPs, relative to open-grown seedlings. Table 4-2 compares mean shoot and root collar basal area growth for eight seedlings (four *L. lanceolata* and four *T. tomentosa*) growing in the absence of matrix trees, versus equal numbers of seedlings growing beneath

matrix trees. These seedlings were all located in the 1989 plot of the Siddapur block. Shade-tolerant *L. lanceolata* grew more in shoot height under matrix trees than it did in the open. *L. lanceolata*'s root collar area growth was similar, whether growing under matrix trees or not. Less tolerant *T. tomentosa*'s shoot growth was similar, whether shaded or not. *Terminalia tomentosa* did grow more in root collar cross-sectional area in the open. However, growth form of both species became branched and bent when growing in the open - which is silviculturally undesirable.

I also witnessed the beneficial effects of MSP matrix trees on seedling growth in a Tirtahalli plantation. One-half of a stand of three-year old mixed seedlings that had not grown satisfactorially was replanted with three m spacings of *Acacia auriculiformis* and *Casuarina equisetifolia*, along with a new cohort of native seedlings. When visiting this plot three years later, both older and younger native seedlings in the portion of the stand receiving supplemental planting consistently displayed greater stem and root collar growth than older seedlings that had received no replanting.

These observations indicate that matrix plantation trees do not adversely affect the early growth of companion understory seedlings. Over the longer term, matrix species should not interfere with understory seedling growth if they are commercially thinned early and repeatedly. Prescribed bi-annual thinnings of matrix species should culminate in complete overstory removal after approximately 14 years. Karnataka foresters should nevertheless exercise care in the selection of

matrix species to preclude the introduction and/or spread of invasive and exotic species. Fast-growing native species with suitable growth characteristics should be selected, tested, and used as MSP matrix species whenever possible.

Finally, the MSP environment also appears to facilitate natural recruitment and succession, when compared to plantations without matrix species. This phenomenon is indicated by the early appearance of unplanted species, like *Syzygium cumini/Eugenia jambolanum* (guava), *Cinnamomum zeylanticum* (cinnamon), *Ixora grandiflora*, *Calicopteris floribunda*, *Piper nigrum* (wild black pepper), *Bulbophyllum* spp. orchids and other epiphytes in plantations near Tirtahalli.

Local Misgivings about MSPs: Reduced Biodiversity and Forest Reservation

Villagers living within the Sirsi Forest Division freely express their displeasure with MSPs - particularly the conversion of minor forest areas to MSPs, as described in Chapter 1. They object that minor forests, degraded though they often are, still produce a wide variety of subsistence products for local people. A forest product use survey conducted by the author in 1992 demonstrated the active use of 67 plant species for 63 different purposes, including: foods, medicines, fodder, building materials, tools, household implements, soaps, cosmetics, sporting activities, and prayer offerings (see Appendix D), to name a few. These 67 species are not a complete representation

of minor forest plant diversity, but they reflect the multiple-use value of minor forests to local people.

Conversion of minor forests to MSPs precipitates ecological changes that reduce their utility to local communities. Site preparation for MSP establishment often kills extant plants immediately, while the plantation trees outcompete many remaining multiple-use species for soil resources, growing space, and light. In the short term, species diversity is reduced by the establishment of MSPs on minor forest sites - even in plantations consisting of 20 or more planted species. As MSPs mature, natural recruitment of native species becomes more evident. Enhanced recruitment ultimately allows site biodiversity to surpasses that of degraded minor forests. However, this recouped diversity may favor commercial timber species over plants having local-use attributes. Twenty or more years and several thinning operations may be required before minor forest sites occupied by MSPs again provide the multiple-use subsistence benefits estimed by local forest dwellers. This is too long for most forest-dependent people to wait.

In the interim, conversion of minor forests to MSPs will cause further reductions in forest areas where local harvest of non-timber products is still permitted by Karnataka State forest laws. Limitation of public access to forests and the non-timber forest products they provide is a process that has long-standing historical precedent. The following socio-economic study begins by documenting the progressive reservation of Indian forest resources by state authority. Reservation of both forest areas

and specific forest products by Indian forest law has spread and intensified over the past 150 years. In this context, MSPs can be viewed as the most recent manifestation of legalized state appropriation of forest resources from local purview.

CHAPTER 5
FOREST RESOURCES IN PENINSULAR INDIA:STATE APPROPRIATION AND LOCAL EXCLUSION

The historical record, both before and after Indian independence, documents the progressive exclusion of local people from forests as a consequence of state appropriation of land. This appropriation gained momentum as the Indian state capitalized the wealth of its forests - creating demand for its forest products in markets across South Asia and around the world. Contemporary popular attitudes about forest management, and multiple species plantation (MSP) silviculture in particular, issue from historical conflict between state forest bureaucracies and forest-dependent communities in peninsular India. Recent rehabilitation of degraded forest areas using MSPs has served to extend local access restrictions to minor forests, areas where local people exercise non-timber use privileges in the absence of such plantations. Therefore, MSPs are viewed locally as a recent form of a centuries-old process of exclusion from forests.

This chapter refers to historical use of Indian forest resources as the base from which progressive state appropriation and capitalization of forests evolved. I adopt a conceptual framework to describe the step-by-step capitalization of Indian forest resources. I then present historical information about forest conservation, silviculture, and recent forest encroachment by villagers in the Sirsi Forest Division - my research area in

northwestern Karnataka. Finally, I introduce forest resource use surveys as investigative tools to 1) document local knowledge and use of forest resources; and 2) to describe impacts of MSPs on a local forest-dependent community.

The Historical Context

Prior to the consolidation of British rule in peninsular India, what are now state-owned forests were controlled by ethnically homogeneous groups, either agrarian communities or hunter-gatherer societies (Gadgil 1989). By 1700 agrarian groups had already deforested the coastal plains and much of the interior plateau region of southern Indian for agricultural use (Richards 1985). Indigenous regional rulers, such as the 18th century's Haider Ali, also removed premium woods from the Western Ghats forests of Kanara District to build ships along the Malabar Coast (Bombay Gazetteer 1883). Such princes were often acknowledged to exercise formal authority over forests (Ashton 1988, Bentley et al. 1987). Local groups nevertheless enjoyed *de facto* use rights to non-agricultural lands in their vicinity (Gadgil 1989). Evergreen forest tracts, or *kans*, were important sources of food, fuel, and fiber for local subsistence. They also provided the organic matter necessary to produce agricultural crops on local wood-ash or *kumri* swidden plots, and leaf mulch to fertilize intensively managed spice gardens. Over time some evergreen *kans* in North Kanara have been designated as sacred groves, indicating a local reverence for them.

Because human survival depended largely on the sustained productivity of neighboring forests, local incentive to protect these assets was strong. In the Himalayan foothills region, Guha (1989) describes an intimate and reverential attitude of local people towards the hill forests that have historically provided their life support and protection from slope erosion. Likewise in peninsular India, clan and community-based institutions arose to manage local forests for posterity and to control non-local access to local forests (Gadgil and Guha 1992). The operation and power of local institutions became legitimized as a consequence of their ability to impose penalties for unsanctioned use of local forest resources. This was often possible because forested regions were isolated from political and economic centers of power on the Indian plains, leaving local forest communities both politically and ecologically independent (Richards and McAlpin 1983).

Local communities did protect and maintain forest resources, as witnessed by early British accounts of the condition of India's peninsular forests, including the Western Ghats region (Cleghorn 1861, Duff 1826,). Even vast natural stands of teak are reported to have been in excellent condition in the Haliyal area of Kanara District (Bombay Gazetteer 1883) when the Indian Forest Act of 1878 became law. This legislation formally inaugurated a period of conflict over Indian forest resources that continues to the present. The period is characterized by intensified exploitation of forests to meet state goals and

interests, and the progressive exclusion of local people from their forest life-support system.

British Colonial Administration of Indian Forest Resources

The British colonial administration in India displayed a marked indifference to Indian forest resources during the 18th century. Nascent European demand for exotic spices, gums, oils, and tropical timber prompted some commercial felling of Indian forests, though on a limited scale (Bombay Gazetteer 1883). Early written records concerning Indian forests, fishing, and grazing resources are insignificant when compared to colonial preoccupation with agrarian resources and property relations concerning ownership and cultivation of arable land (Grove 1990, Richards and Tucker 1988). Subsidies and inducements encouraged cultivators to clear lands along India's forest frontier. Forests were viewed more as impediments to the expansion of cultivation and its associated revenue potential. Along the Malabar Coast in southwestern India, no forests were turned into protected reserves until 1806 (Guha and Gadgil 1989).

In 1816 the first Conservator of Forests was appointed in India to sanction the East India Company's teak (*Tectona grandis*) extraction monopoly (FAO Forestry Paper 55 1985). Exploitation of abundant natural teak stands began in Malabar and Travancore to supply timber for construction of British navy ships, since imperial forests in North America had been surrendered as a result of the American Revolution. More forests were felled to plant coffee, tea, cardamom, and other export crops after the

East India Company transferred India's administration to the British Crown in 1858. Establishment of the first scientifically-managed government plantations began from 1865-1870 (Agarwala 1985).

Construction of India's first railways in the late 19th century initiated significant, large-scale exploitation of South Asian forests. From 1870 to 1910 railway networks expanded seven-fold, from 7,678 to 51,658 kilometers (Guha and Gadgil 1989). The larger network required numerous railway ties, that soon became a locally scarce commodity. In 1864, according to the wishes of the Governor-general, Lord Dalhousie, India's first forest department was established to meet an annual demand of 1,000,000 ties for the railway companies. Experienced German foresters, of whom Inspector-General of Forests Dietrich Brandis (Richards and McAlpin 1983) was the most prominent, were hired by the British to place government forests under a rational form of European silviculture.

The Indian Forestry Act of 1865 sanctioned the establishment of government forest reserves, and extended the state monopoly of teak to other commercially important species, including rosewood (*Dalbergia latifolia*), sandalwood (*Santalum album*) and ebony (*Diospyros ebenum*) (FAO 1985). This legislation also claimed government authority to set forest use rules and to impose penalties for use infractions. While local access to forests for grazing, fuelwood collection, and timber felling was still permitted in practice, such use could henceforth be regulated by

government decree. This established a legal structure to sanction subsequent state demarcation and reservation of forests.

The Indian Forest Act of 1878 consolidated absolute government authority over utilization and management of newly designated reserved forests (Grove 1990). By 1882, 34 square miles (4.9 %) of forests had been reserved in the Sirsi Forest Sub-Division, out of a total of 700 square miles. In Kanara District as a whole, 684 (19 %) of 3,549 square miles of forests had been reserved (Bombay Gazetteer 1883). The 1878 laws also established so-called protected forests, areas that would become reserved forests after demarcation and preparation of silvicultural prescriptions.

Understanding that future production of timber could not be guaranteed if customary local forest use rights continued, the government also placed restrictions on local use of protected forests under the 1878 act. Nineteen species of trees and four forest products became reserved solely to the government. These species were: *Tectona grandis, Santalum album, Dalbergia latifolia, Diosporos ebenum, Pterocarpus marsupium, Calophyllum elatum, Artocarpus integrifolia, A. hirsuta, Vitex altissima, Ougenia dalbergioides, Lagerstroemia microcarpa, Gmelina arborea, Terminalia tomentosa, T. chebula, Xylia dolabriformis, Thespesia populnea, Acacia catechu, A. concinna,* and *Bassia latifolia*. The four reserved products were: fruits of *Terminalia chebula* (hirda), fruits of *Acacia concinna* (shigikai), flowers of *Bassia latifolia* (ippe huva), and latex from *Acacia catechu* (kath).

These products, such as hirda fruits, could only be gathered by locals under forest department contract.

The colonial government also redefined previous customary forest use rights granted to local people as use "privileges" in protected forests. The chief privileges still permitted were: 1) clearing patches of forest for wood-ash or swidden tillage; 2) lopping leaves for green manuring of spice and betelnut palm gardens - garden owners were restricted to lopping only in designated *soppina betta/betta* forests tracts that were no more than eight times the area of their garden holdings; 3) growing pepper in some evergreen *kan* forests; 4) free grazing in designated forest tracts; and 5) free or cheap wood fuel and bamboo collection (Bombay Gazetteer 1883). The sale or barter of protected forest products was strictly prohibited. The penalty for doing so was often the loss of all collection privileges.

Village forests were designated close to villages, to be administered by village councils (Village Forest Panchayats) for multiple use by local people. Local use of reserved species and products was also illegal in these village forests.

The Indian Forest Act of 1878 formally initiated the process of supplanting village-based customary forest use agreements by centralized government. Physically limiting local access to forests, and progressively converting local forest resources into commercial commodities for distant markets were pivotal elements in this transfer of authority (Gadgil and Guha 1992). Before 1878, forests had been exploited in a non-intensive manner. Trade and commercialization of forest-derived surpluses had been

limited to commodities like wild pepper and cardamom, medicinal plants, sandalwood, ivory, and a few timber species. Agrarian communities on India's plains had little interest in Kanara's forests for other than a small number of such products, and extraction of these did not have a serious impact on the ecological function of Kanara's forests. After 1878, forests were considered to be sources of revenue from timber production. Silvicultural strategies to maximize timber revenues led to changes in forest species composition that favored conifers over mixed oak hardwood/conifer forests in northern India, and pure stands of teak over mixed evergreen hardwood forests in peninsular India (Guha 1989).

The 1878 laws also initiated the ecological separation of forests from agricultural activities (Guha and Gadgil 1989). Once reserved, forests could no longer legally provide inputs to maintain soil fertility in neighboring fields and gardens. The threat of falling agricultural yields prompted the Forest Policy Resolution of 1894 (Haeuber 1993), which stressed the need to clear forests for local agricultural extension. A tightening vice of accelerated forest conversion on the one hand and continued forest reservation on the other squeezed local forest use into shrinking forest tracts of inferior quality.

Finally, the 1894 laws modified forest classification into more nearly its present form. Reserved forests were distinguished as either Protective or National Forests, village and less productive forests were renamed Minor Forests, and grazing areas became Pasture Lands (Haeuber 1993). *Betta* Forest

zones and their classification were maintained. Formal prescription of *bettas* as lopping forests would be delayed, however, until the 1924 Forest Act. The 1924 Act would also set limits on local usufruct privileges in Minor Forests.

Ecology and Aesthetics of Forests: Colonial Perceptions

While acquiring a global reach over natural resources for the purposes of trade, some Europeans also asserted control over their territories based on ecological considerations. A small number of 19th century colonial forest conservationists promoted forest reservation in dozens of colonial territories (Grove 1990), including India, to redress environmental degradation. This group popularized a theory linking deforestation to undesirable rainfall and climatic changes (Grove 1990). A minority of British officials warned that the unchecked expansion of agricultural lands would, through a process called desiccation, cause the loss of valuable timber resources, mass deforestation, and environmental cataclysms throughout India (Richards 1985). Informed scientific authorities of colonial island territories reported the destruction of soil and water resources when forested uplands were converted from forests to agricultural lands.

Another perception that spurred some British to espouse a forest reservation agenda had an aesthetic or Edenic slant (Grove 1990). A paradisal image of pristine tropical lands was strongly imprinted on European minds. With time and travel these views were transformed into fascination for collection and classification of tropical flora, or game hunting of tropical

wildlife. The boundaries of many ecological reserves were, therefore, defined by colonial states to set aside regions of diverse flora and fauna for the enjoyment and recreation of Europeans.

Local Resistance to Capitalization of Forests

Finding their entry to local forests barred by legal injunction in the 19th century, local communities petitioned governments for compensation. In the years prior to 1878, many such protests were diffused by flexible and well-informed forest officials, who acknowledged many sustainable local forest use practices and recognized protest over their proscription as legitimate. Cleghorn (1861) acknowledged that local tribes were, in fact, less destructive of forests than invading plains cultivators, and investors in plantations. But petition and protest often went unrewarded, and were entirely ignored after the passage of the Indian Forest Act of 1878.

Finding petition unsuccessful, law-breaking in the form of illegal wood gathering, grazing, tree felling, and smuggling of state forest resources became common. Arson of state commercial forests also served to convey indigenous displeasure at being barred from ancestral forest lands. However, locals were careful to destroy only single-species stands that symbolized the interests of capital, and not the mixed species stands that embodied multiple-use attributes from a subsistence perspective (Guha and Gadgil 1989).

In an advanced stage of resistance, alliances between traditional elites and peasants emerged when British denial of

customary forest use rights became intolerable across Indian classes and castes(Grove 1990). From the crown's perspective, control of forests then became tantamount to control of political dissent, since organized forms of resistance appeared to openly flaunt British authority. Forest conservancy was intensified, and forcible suppression was sometimes used to quell these organized insurrections. The threat of locally-caused destruction of forests was often used as a pretext for enhanced political suppression of Indians.

Whether intended to sustain the colony's resource endowment, to provide short-term profit and pleasure, or to maintain political power, colonial reservation of forests led to a state monopoly of India's forests.

Management of Indian forests in the early 20th Century

Extension of colonial authority over forests was sanctioned by the Indian Forest Act of 1927. This act reiterated the forest management framework of 1878, while also allowing the government to assume control of many forests that it did not already own (Haeuber 1993). It also enumerated situations in which forest department officials could arrest without a warrant those accused of forest resource theft.

Administration of forests was placed under federated provincial auspices in the Government of India Act of 1935, a decade prior to Indian independence. Henceforth, forest administration would be directed by state governments, with central government involvement limited to forestry policy, education, and research. This historical delegation of authority

explains wide variations in the programs, methods, and effectiveness of forest administration to be found among the states of modern India. Contemporary discussions about Indian forestry or forest administration must, therefore, be prefaced by clear reference to a particular state or territory. Such differences among states not withstanding, rates of forest conversion increased throughout India after independence. Growing population, impoverishment of the environment, and global economic forces joined together to insure the conversion of all but India's most remote and inaccessible natural forests.

A final reformulation of forest policy in British India came in a 1944 statement issued by the inspector-general of Indian forests. It represented a last effort to reconcile the conflicting management priorities of state forestry officials and Indian nationalists. The former perceived stricter control of local forest access and use as essential to successful timber production in state reserves and protected forests. The latter called for formal recognition of the dependence of India's rural poor on forest resources for their survival. The 1944 statement gave the needs of agricultural production priority over production forestry, and local subsistence priority over the generation of state revenue (Haeuber 1993). However, this compromise had little impact on the day-to-day management activities of state foresters. Enforcement of forest protection laws went unchanged.

Post-Colonial Management of Forest Resources

After independence the newly formed Central Board of Forestry formulated the 1952 Government of India Resolution. It recommended that forest lands occupy one-third of all Indian territory, and that 60 percent of hill regions and 20 percent of the plains should remain forested. Actual percentages continued to decline below these recommendations, however, as few funds were earmarked for reforestation. The growing commercial emphasis on production forestry to promote national self-reliance became the new nation's priority. Previous rights of indigenous, tribal forest-dwellers to collect fuelwood, timber, and fodder in reserved forests were progressively revoked (Haeuber 1993), while the ability of state governments to reserve forest lands grew apace. Indeed, expansion of reserved state forests accelerated after independence. In 1992 the modern Sirsi Forest Division contained approximately 70,000 ha of reserved forest - 41 percent of all forests. Fifty thousand ha of minor forest, and 50,000 ha of *betta* forest comprised the remaining divisional forests (1992 interview with divisional forestry officer).

With the integration of princely states into the Indian Union in the early 1950s, royal hunting preserves of forests, woodlands, and grasslands also came under the purview of empowered state departments of forestry. Local communities that had previously relied on such lands to provide a variety of household, farming, fodder, and dietary requirements found that their use of state-managed forests had become entirely regulated.

Any of their remaining use privileges were now formally described as "concessions".

The Indian National Commission on Agriculture (NCA) forest management recommendations of the early 1970s gave top priority to industrialization of the Indian forestry sector as the vehicle to boost timber exports and foster import substitution. The NCA blamed declines in forest commercial productivity on local forest encroachment and illegal removal of forest products. Their recommendations emphasized conscription of all unclassified forests into reserved forests as soon as possible, in order that local forest use concessions be terminated "as far as possible in the manner provided in the forest law." (Government of India, Report of the National Commission on Agriculture, Part IX,4:8) To compensate local people for their loss of these forest use concessions, forest department distribution depots were established to sell forest products to them at cost. Today, many villagers remain embittered by having to purchase from government depots what they formerly gathered in local forests at no charge.

The NCA also recommended reclassification of forests to conform with an industrial production orientation. Uplands, steep slopes, and riparian zones were consolidated as protection forests. Production forests were of three types: low-value mixed quality forests targeted for complete felling and replanting; valuable forests that could still be economically improved by conversion planting; and inaccessible forests that would be exploited after forest roads reached them. The most deforested tracts were reclassified as social forests. These included

degraded minor forests, wastelands, village commons, and road and rail right-of-ways (Viksat 1990, Haeuber 1993). Local community use of non-reserved products obtained from social forests was offered in compensation for lost local access to newly-classified protection and production forests.

State governments failed to invest in replanting or other rehabilitation schemes in social forests, favoring investment in production forests instead. Policy makers interpreted social forests to be commercially expendable tracts to which local use pressure could be redirected in lieu of more valuable production forests (Shiva 1988).

Forest management legislation initiatives in the 1980s heightened debate over the future of Indian forests. Jurisdictional conflict between state and federal agencies over control of forests was touched off by the Forest Conservation Act of 1980. This amounted to a legislative last stand at the federal level to prohibit clearance or conversion of forests to other land uses without parliamentary approval (Government of India Report of the National Commission on Agriculture, Part IX). State governments balked at this interference from the central government. However, state forestry departments were quick to seize upon this legislation as an opportunity to strengthen state control of forest lands - particularly in the area of law enforcement. The 1980 Act strengthened the severity of fines and punishments for illegal activities in state forests. It granted forest officers the right to arrest offenders without a warrant for tampering with boundaries, setting fires, gathering reserved

products, and cultivating forest lands (Haeuber 1993). Local forest use concessions in all forest types were further restricted. The act also called for the initiation of forest rehabilitation in degraded forests and other wastelands throughout the country. Soon thereafter, the proposed Indian Forest Act of 1981 recommended authorizing state governments to reclassify any lands they wished to as "forests" (whether forested or not), in order to enhance public control over both tree and non-tree derived forest resources (Kulkarni 1983).

Since 1981, the dispute over disposition of India's forests has continued between state and federal authorities on the one hand, and state forest departments and forest dwellers on the other. Government officials blame villagers for their indiscriminate use and destruction of forests, while the latter blame government-sponsored industrial forestry operations for conversion of India's remaining natural forests. Recent warnings about the environmental consequences of Indian deforestation (Shiva 1990) and its possible mitigation do not seem to have made a serious impact on those wielding political influence. Public media battles continue over control of India's residual forest wealth, rather than over its maintenance and reproduction.

Capitalization of Indian Forest Resources: An Analytical Framework

The historical capitalization of Indian forest resources described above is summarized by Nadkarni's (1989) analytical framework of forest conversion and capitalization. Nadkarni

(1989) outlines three historical stages of forest use and conversion: the pre-commercial-cum-pre-capitalist stage; the initial commercial stage; and the highly commercialized stage. In the first stage, nature's forest bounty is an abundant and free gift for one's personal use - not intended for commercial sale. Forests are an important source of many subsistence products for household use. Unsophisticated technology precludes regional-scale conversion of forests for subsistence purposes. Destruction of forests sometimes does occur, however, because the resource is not considered scarce. The use of fire as an effective tool in preparing land for short-term agriculture is an example of such destruction.

British officials generally considered the customary burning of forest tracts in Indian swidden agriculture, or *jhuming*, as a primitive and uneconomic landuse practice to be discouraged (Grove 1990). Yet *jhuming* had been practiced for generations in an apparently sustainable manner by agrarian societies over large tracts of the interior Indian Plain (Ramakrishnan 1980). Only a small percentage of land was under cultivation at any one time, while fallow areas were rested to naturally recoup their fertility for future cultivation. Large expanses of forest cover were always maintained within traditional *jhuming* systems.

In the second or initial commercial stage, a perception of resource scarcity arises as external market forces begin to assert control over forest resources, at the expense of local forest-based communities. Emphasis on intensified production of a few commercially viable timber species and products

necessitates the exclusion of local people from forests. Once this occurs, traditional common property stewardship arrangements begin to break down (Bromley 1991). Local princes, small merchants and *savkars* (merchant moneylenders) employ formerly autonomous members of local communities to extract high value forest products in exchange for wages (Richards and McAlpin 1990). Agarwal and Narain (1989) describe this as the progressive alienation of local communities from their forests. Bromley and Cernea (1989:35) describe this transformation as follows:

> Common property is in essence 'private' property for the group and in that sense it is a group decision regarding who shall be excluded. But when options for gainful and promising exclusion of excess population have been destroyed by surrounding political, cultural, or economic events, then those engaged in the joint use of a resource are left with no option but to eat into their capital.

In the third, highly commercialized stage, forest resources become the raw materials of external, forest-based industries. Large, mechanized, and centralized factors of industrial production subjugate regional merchant capital. Local access to forests is further diminished as commercial forestry promotes controlled conversion of native forests (Bee 1990) and regeneration of managed plantations. An open access free-for-all of intensified degradation occurs in the few natural forests to which local access remains less restricted (e.g. village or minor forests). The impoverishment of local communities proceeds as

these scarce forest resources are destroyed by those who most depend upon them for subsistence (Richards 1985, Kaur 1991).

As state control of forests expands, forest-dwelling communities find a bureaucracy of state forest officials positioned between themselves and the now restricted forests. To obtain access to state lands, peasants must find favor with department officials or with neighbors powerful enough to influence forest department staff (Blaikie and Brookfield 1986). If either of these strategies fails, individuals are often forced to survive by ignoring forest access laws to extract their basic material needs from public forests. Given this situation, in which forests are under attack from all quarters, Nadkarni maintains that management of forest resources must finally enter a fourth, enlightened stage of systematic and rational management. This stage emphasizes conservation and regeneration of forest resources for both local subsistence and regional commercial needs (FAO 1985, Agarwala 1985). A model for enlightened, joint forest planning and management between state foresters and local people will be presented in the final chapter of this study.

Forest Policy and Management in Northwestern Karnataka State

In the 1935 Government of India Act, promulgation of constitutional laws regarding natural resources remained a federal prerogative, while practical management of forests fell to state departments of forestry. The Karnataka Forest Department's (KFD), descending directly from colonial precedent,

was inaugurated with the establishment of Karnataka 1956. Due to the relative wealth of forest resources in Karnataka, state foresters assumed conservancy of this natural legacy in as serious a manner as did their colonial predecessors.

Karnataka's forests are among India's most diverse in biological terms, but for legal purposes they comprise three primary types: reserved forests, protected forests, and minor or village forests. In reserved forests only limited single tree felling occurs, and this is done exclusively by state foresters. From 1985 until 1991 an even more restrictive policy of only dead and down tree removal was adopted by an environmentally-minded chief conservator of forests. In contrast, protected forests include both natural and manipulated stands under commercial silvicultural treatment. An increasing number of protected forests have been converted into plantations as their mature trees are harvested. The state's most degraded stands have been classified as minor or village forests. These have been designated for local harvest of non-timber products in specified quantities.

A fourth class of forests is found only in the upper Ghats of Yellapur, Sirsi, and Siddapur Taluks (sub-districts) - *Soppina betta* forests. These forests were first designated as so-called lopping forests in the late 19th century, providing green manure/mulch usufruct privileges to those who owned betel nut (*Areca catechu*) gardens. Eight to nine acres of *soppina betta* lopping forest were traditionally allocated for every one acre of spice garden owned by landed cultivators. Spice garden

owners with *betta* privileges have historically had no formal role in *betta* forest management decisions made by the state.

Private tree felling is prohibited in all forests, with the exception of *betta* forests, where authorization to remove single trees for subsistence purposes has been occasionally granted to spice garden owners since 1977. The highly degraded condition of minor forests, however, attests to the historical inability of state foresters to enforce felling regulations. Conversely, the will to enforce felling regulations is often lacking, as local forest officials sometimes receive payment to look the other way when felling occurs.

Like the British before them, Karnataka's foresters follow prescriptions to enhance the biomass productivity of selected timber species, often in uniform plantations (Agarwala 1985). In this market-oriented silviculture, local people receive jobs as forest department personnel or daily wage laborers - often the only form of seasonal employment locally available. Forest managers take silvicultural control of forest ecosystems as quickly as technology and finances permit. Economic goals drive all stages of such production forestry.

From the 1960s to mid-1980s several unrelated events began to discourage Karnataka foresters from continued planting of single species plantations. The invasiveness of exotic understory plants, particularly *Eupatorium* sp., massive insect defoliation of teak plantations, and mismatching of plantation species to inappropriate sites made the maintenance costs of many

marginal stands greater than the expected economic returns. A reassessment of silviculture practices began.

Forest policy initiatives of the 1980s began to stress rehabilitation of India's degraded forests and wastelands. This new policy climate presented Karnataka foresters with an opportunity to assert silvicultural control over state forest lands that had been previously neglected - particularly minor forests. By 1982 the first of what would become annual plantings of multiple species plantations (MSPs) began. Replanting of degraded forests, especially minor forests, to MSPs gained momentum during the 1980s. The silvicultural component of this study was conducted in MSPs planted on minor forest lands in 1988, 1989, and 1990.

Prevailing opinion of foresters about MSPs centered on the need to rehabilitate impoverished forest lands - forests that had been damaged through irresponsible overuse by local people. Though this opinion was often justified, foresters failed to acknowledge two characteristics of minor forests and MSPs that were abundantly clear to local people: 1) though degraded, minor forests still provided local people with many products necessary for their welfare; and 2) MSP establishment effectively excluded local people from forests where they had previously enjoyed access to collect non-timber products.

Pushing Back the Forest Frontier: Forest Encroachment in Sirsi Taluk

Another process that diminishes public access to forest resources in Karnataka State is forest encroachment. In Sirsi Taluk, for example, forest felling and expansion of village land has been occurring continuously for at least 150 years (Bombay Gazetteer 1883). During most of this period sanctioned encroachment of forest land was recognized by state and federal agencies. Whenever there was a need to expand agricultural and residential lands for distribution to landless people, the State Revenue and Forest Departments would institute so-called "disforestment". This involved the removal of forest lands from Forest Department records and their transferal to Revenue Department records. The forest settlement officer in the Revenue Department was charged with carrying out this task.

Forest conversion was first codified into law by the Forest Policy Resolution of 1894. Public outcry for greater access to forest lands for homesteading and agricultural expansion necessitated further opening of the forest frontier. Though forest settlement was the centerpiece of this act, state control of reserved forests was simultaneously strengthened. In practice, disforestment amounted to transfer of less productive and degraded forests to private cultivators, and state reservation of productive forests. The 1894 act also set legal precedent for recurrent titling of encroached forest lands - a

popular program that would become a tool of post-independence politicians to garner votes during election years.

Prior to 1980, forest land encroachment was legally recognized, or regularized, on a continuous basis. Regularization is provided for by the Kanara Forest Privileges Rules of 1911. People were given legal title to forest lands called *patta*, while cutting of any forest trees remaining on this land was normally prohibited by the KFD. Some forest lands were also given on a temporary lease basis, and many of these areas have not been regularized (Tax Collector's Records, Sirsi Taluk). All regularization of encroached forest lands ended in 1980 when the Forest Conservation Act became law.

Since 1980, encroachment onto state forest land has remained a common practice in Terkanahalli Village, as is the case throughout the Sirsi Taluk. Tax records for two villages indicate that 90 percent of land owners have in some manner encroached on forest land. Average size of encroached parcels varies from 0.2 to 1.75 ha. Landless people also encroach on forest land. This is normally done in order to build homes. The size of these parcels averages 0.1 to 0.8 ha (Tax Collector's Records, Sirsi Taluk). Villagers who have not encroached on forest land do not live adjacent to forest land. Some of these people have, however, encroached on forest land elsewhere.

The illegality of forest encroachment is a consequence of India's Forest Conservation Act of 1980, which stipulates that no forest land shall be used for any other purpose than forest production, except by consent of the federal government. Since

1980, unsanctioned encroachment of forest land has therefore necessarily become the norm. Revenue Department record-keeping of newly encroached land was discontinued in 1980-81. This is because any official record or recognition of encroachment can serve as a basis for, or potentially facilitate, subsequent titling of encroached land to villagers.

Due to political pressure in 1991-92, the Karnataka State government again initiated regularization of encroached forest land, but only for lands placed under cultivation before 1970. Recent regularization efforts indicate that politicians give higher priority to the resource demands of vocal local communities than to national environmental legislation. Though forest encroachment by growing numbers of the rural poor is often politically expedient, the inevitable result is further disappearance of Indian forests.

Conclusion

This chapter has outlined the progressive appropriation of Indian forest resources by the public sector - at the expense of forest-dependent communities. Multiple species plantation (MSP) silviculture is described as the most recent effort by Karnataka forestry officials to reduce local access to the few forests where villagers may still collect non-timber products.

Conversely, MSPs may represent a sincere state effort to improve the productivity of degraded minor forests, simultaneously improving the welfare of local forest-dependent communities. Community-oriented strategies have been

successfully undertaken to reforest degraded public forestlands in West Bengal (Malhotra and Poffenberger 1989), and to establish community buffer zones around wildlife reserves in Gujarat (Groenfeldt et al. 1990). In 1993 the Karnataka Foresty Department (KFD) adopted a joint forest planning and management program for several Karnataka districts. These initiatives suggest that Indian state forestry bureaucracies are beginning cooperative management of public forestlands, to enhance the welfare of both local communities and forests. Can the recent KFD initiative rehabilitate forests, while at the same time benefiting forest-dependent communities?

To address this question I employed two forest resource use surveys as investigative tools to: 1) document local knowledge and use of forest resources; and 2) describe impacts of MSPs on a local forest community with respect to gender, caste, and age. The surveys were also structured to explore some policy and management options that could facilitate compromise and cooperation between state forestry authorities and private users of the forest. The final three chapters of this research present these surveys, their results, and the pathways to compromise that they suggest.

CHAPTER 6
THE COMMUNITY FOREST RESOURCE STUDY: THE BASELINE SURVEY

Introduction

This chapter describes the testing, administration, and analysis of a forest resource use baseline survey, developed to address the following questions:

1) Who are the local, forest-dwelling people in the survey area, and how do they use local forest resources?

2) Do Karnataka Forest Department's (KFD) multiple species plantations (MSPs) provide enhanced benefits to these local people, when compared to the benefits they previously enjoyed from the forests MSPs have replaced?

3) If benefits from MSPs do accrue, but are unevenly distributed within forest communities, what groups are affected and in what ways?

4) How might MSP management be improved to produce those forest products most needed by groups dependent on forests for their subsistence?

The baseline or general survey adopts caste affiliation, gender, and age as independent variables to distinguish intra-community differences in informant knowledge of forest plants and products derived from them. Reported uses of forest resources in minor forests, and minor forests already converted to MSPs are compared for all intra-community groups. This tests whether the presence or absence of MSPs has any effect on forest-dependent

communities. Local *betta* forest use information is also provided for those Havik Brahmins who have usufruct privileges in them.

The baseline survey also solicits informants' suggested improvements to MSPs that would better respond to their own subsistence needs and forest use priorities. These responses include local preferences about: desirable tree species for planting, lands where new forests ought to be planted, and how future reforestation programs should be implemented.

The Forest Resource Use Study: A Two-Tiered Approach

The range of views about forest and MSP resources, the gender, caste, and age groups that profess them, and improvements or alternatives to MSPs suggested by each group are the central foci of two surveys undertaken in this study - the baseline and forest resource use surveys. Baseline, or general community information is essential in this context, for it affords familiarity with communities affected by the advent of MSP silviculture. The most direct method to collect baseline data about people and their use of forest resources is to observe and document their interactions with a forest environment for an extended period. This process usually involves tallying items that people collect from forests, learning how the items are used locally, how they are collected, how much of each is collected per harvest interval, how important each item is to community socio-economic welfare, and how sustainable local collection practices are. Investigators use a variety of survey techniques

to gather and analyze such baseline data, including the semi-structured survey format used in this study.

If more specific information is sought, however, a second and more detailed survey (see Chapter 7) instrument becomes necessary. The forest resource use survey focuses on informants' knowledge of forest plants, and their opinions about the plants they recognize. If properly constructed, a detailed survey may reveal informant use of both existing forest areas and the MSPs that are now replacing them. This line of inquiry can identify the extent of opportunities gained or lost when MSPs spring up on minor forest land next to forest-dependent villages.

Hypotheses of Caste, Gender, and Age to be Tested by the Surveys

Caste affiliation has been shown to mediate the management and use of natural resources elsewhere in India (Gadgil and Guha 1992). Caste is also expected to distinguish knowledge and use of forest resources, and the benefits they provide to villagers. Knowledge and use of forest products should increase as a function of increasing caste dependence upon these products for subsistence. Castes owning more agricultural land or having economic alternatives beyond the forest are expected to be less knowledgeable about forests, and to be less affected by their conversion to MSPs. However, due to reduced plant diversity in young MSPs, all caste groups are expected to report that MSPs are less useful to them than the minor forests they replace.

Women are expected to have greater knowledge of forest products than men, as they have been observed to visit forests more frequently to collect such products.

Older people are expected to possess more forest-based knowledge than younger people, due to their longer experience in acquiring forest skills and lore.

Conversion of forests to MSPs should have little or no impact on community members oriented towards urban economic pursuits, in which forest resources play no part. These groups are expected to have the least knowledge of forests, regardless of gender, caste, or age.

The Baseline Survey

Creation and Administration of the Baseline Survey

Terkanahalli Village was selected as the survey study area from a pool of four rural sites, all of which had been repeatedly visited in the course of silvicultural research. While most Indian villages I visited maintain a considerable degree of caste or ethnic homogeneity, Terkanahalli is a mixed village. Within its political boundaries members of 12 different caste groups live in 11 residential groupings or hamlets. Hamlets are the most relevant units of rural social organization, being predominantly caste-based (Agarwal and Narain 1989, Groenfeldt et al. 1990). Formal villages (Gram Panchayat) often encompass several caste-specific hamlets, making intra-village caste-based differences profound.

Terkanahalli is within the field jurisdiction of Mr. C. Saibaba, an officer at the District Commissioner's Office in Sirsi Taluk. Mr. Saibaba understood my research interests and described Tarakanahalli as a suitable area for the administration of the forest use surveys I envisioned. He also facilitated my entry into the area, and the subsequent collection of survey information by hired female assistants.

The two field assistants were sisters who live in a village 12 km east of Terkanahalli along the Banvasi Road. They were recommended to me by the director of a non-government development project in the Western Ghats region. Both women were in their early 20s. The younger was a student and the other a graduate of a two-year teacher's training college in Sirsi. Both lived on a working farm and were adapted to a rural lifestyle.

A semi-structured survey of 25 questions was formulated for use in the study's baseline phase. Employees of both government agencies and non-government development organizations guided me in formulating specific questions that would not be perceived as intrusive. The survey solicited information about informants' households, their forest resource collection and use activities, and their opinions about government MSPs and how they could be improved to better meet local forest use requirements.

To test the baseline survey, my two assistants first administered it to my neighbors in Sirsi Town. As a result of the test, the survey format and language were changed when confusing or inappropriate, and the survey's overall length was shortened. I then accompanied my assistants to Terkanahalli, to

observe them while two more survey trials were done with villagers sitting at a bus stop on Banvasi Road. After the assistants had virtually memorized the survey format, and divided administration and recording tasks among themselves, they entered Terkanahalli to do two final trials in households by themselves. Having completed these final trials, they came to Sirsi to review what had occurred with me. The veracity of trial responses concerning family membership, land ownership, income category, and livestock holdings was also checked against the District Commissioner's records by Mr. Saibaba. Responses agreed with local tax records. A final, revised survey format was adopted by me and my assistants, and photocopied for interview and recording purposes (see Appendix A).

During April and early May 1992, my two assistants independently visited each hamlet in Terkanahalli to conduct the baseline survey in 122 of 140 households. Each survey required approximately 30 minutes to administer, and sampled all 12 village caste groups. At least four informants were selected from each caste group. If there were fewer than four households representing a particular caste in the survey area, then an informant from every household in such under-represented castes was interviewed. Eighty-five of the informants were female, while 37 were male. Females were intentionally oversampled since they are most commonly involved in the collection of forest resources for personal and household use.

Caste Groups

Twelve distinct caste groups participated in the Terkanahalli Village baseline survey.

1. Havik Brahmin: This is the majority land-holding group. Ninety-five percent of all Havik informants own their own lands. The largest group of Dravid or southern Brahmins in Kanara, Haviks probably migrated from northern India by sea at the end of the 7th century (Bombay Gazetter 1881). Intensively-managed *Areca* nut/spice garden management is the primary occupation of most lay Haviks. These lucrative gardens are usually located on fertile alluvial bottom lands. Annual green manuring from *betta* forest loppings and sophisticated gravity-fed irrigation networks sustain garden productivity. Some Haviks have non-farm business interests. One-third of all households in the survey area are Havik Brahmin. This group commands economic and political respect in Kanara, and is prominant in state-level politics as well.

2. Lingayat: Processing of oil seed is the historical occupation of many Lingayats. This group migrated south into Kanara from Dharwad about 200 years ago. Hard-working small merchants and farmers, this group has economic influence and brahminical status.

3. Sonar/Shet: Believed to have moved inland from Goa after its conquest by the Portuguese in 1510 (Bombay Gazetteer 1881), this group of goldsmiths has taken the honorific "Shet" after surnames. Five of the 9 Sonars interviewed own their agricultural lands. A rising class economically, Sonars claim brahminical origins. Other Brahmins, however, perceive them to be of intermediate status.

4. Namadhari Naik: Migrating into the Western Ghats from the Malabar Coast, this group has agricultural roots. Fifty percent of those surveyed own their own land, while one-third work as agricultural laborers. A few have local business interests. Formerly weak economically and politically, Namadhari Naiks are an emerging force in Kanara political affairs.

5. Badagi: A ubiquitous local group of carpenters, blacksmiths, and manufacturers of agricultural tools, two of five Badagis interviewed own their agricultural lands. Badagis hold an intermediate position both economically and socially.

6. Muslim: Muslims migrated from northern India into the Kanara area of Karnataka about 100 years ago. More recently, they have moved from Sirsi into rural communities like Terkanahalli. Small business owners and urban landlords, none of the 11 Muslims interviewed own agricultural land. Living adjacent to Banvasi Road, most work as unskilled laborers locally or commute to work in Sirsi. While their economic position is weak, Muslims are well-organized and assert themselves politically.

7. Poojari Naik: This group originates from coastal South Kanara District and is still concentrated there. Agricultural laborers, small business entrepreneurs, and government employees, few Poojaris own land. None of the four Poojaris interviewed own land. A local minority, this group is weak economically and has a relatively low social position.

8. Kodiya: Kodiyas are barbers who have moved inland from coastal areas. None of the three Kodiyas interviewed own land. Besides cutting hair, many work as agricultural laborers. This group is weak economically and has a low social position.

9. Patgar: Having migrated inland from coastal areas, Patgars work as agriculture laborers, government employees, and a few own small businesses. The single Patgar woman interviewed owns some irrigated rice land and two animals, a cow and a buffalo. This group is weak economically and has a low social position.

10. Maratha: Maratha migration south into Kanara from Maharashtra occurred about 500 years ago. Only one of the seven Marathas interviewed own land. Others work as agricultural laborers. Marathas have historically collected bamboo and canes from minor forests for processing and sale. This is a poor group, having a low social position.

11. Vokkaliga Gowda: This is a scattered minority in Kanara's interior, but large enclaves of Vokkaliga Gowdas are found in coastal North Kanara. While few own land, five of the seven interviewed lease cultivable lands. Not to be confused with pastoral "gowdas" in other regions, this group is economically weak, has low status, and is unrepresented politically.

12. Moger: Primarily fishers originating from coastal areas, Mogers work as agricultural laborers for others. Mogers are considered an underprivileged community - a scheduled caste, and are the focus of central and

state government affirmitive action programs. This group has the lowest social status.

Hamlets

Terkanahalli Village comprises 11 hamlets. Informants from each hamlet were included in the baseline survey. Particular caste groups predominate in specific hamlets, physically separating themselves from other groups. Local minority castes also keep to themselves spatially, but sometimes share hamlets with other minorities. Integration of minorities is most frequent bordering Banvasi Road, allowing landless groups convenient access to employment and market opportunities beyond the village. Some, but not all groups living in hamlets close to Banvasi Road, collect no forest products at all. In such cases forest products are purchased from other caste groups that collect surpluses. Apart from this roadside-interior distinction, the effect of hamlets on local forest use was not apparent.

Gender

Eighty-five females and 37 males were interviewed. Females were intentionally over-sampled in Terkanahalli, since there they are most commonly involved in the collection of a variety forest products for personal and household use. Table 6-1 shows the distribution of individual survey informants by gender and caste.

Table 6-1. Gender and caste distribution of baseline survey informants

Caste	Females	Males
Havik Brahmin	24	16
Lingayat	2	0
Sonar/Shet	7	2
Namadhari Naik	19	10
Badagi	5	0
Muslim	9	2
Poojari Naik	3	1
Kodiya	3	2
Patgar	1	0
Maratha	5	2
Vokkaliga Gowda	7	0
Moger	0	2

Age

Informants varied in age from 18 to 94. Age distribution by 10-year intervals is presented in Table 6-2. This table indicates large numbers of female informants between 20 and 29 years of age. The interviewers felt that this was because they, too, were women in their 20s. They reported that women in their 20s were uniformly enthusiastic to answer the survey questions, and were not refused.

Table 6-2. Age distribution, by 10-year intervals, of baseline survey informants

Age Interval	Females	Males
Teens	2	1
Twenties	29	6
Thirties	19	9
Forties	11	6
Fifties	14	4
Sixties	4	7
Seventies	3	4
Eighties	2	0
Nineties	1	0

Marital Status

Only eight informants were unmarried: three females under 30 years old, a 30 year-old female, three males under 30 years old, and a 34 year-old male. In this region, as in much of rural India, females normally marry before the age of 20, and males in their early 20s (VIKSAT 1990).

Literacy

Local usage of the term "literacy" extends to those who are only able to write their own signature, irrespective of educational background. Because of this interpretation, reported literacy appears greater than functional literacy - the ability to read and write at a junior high school level. Caste distribution of households in which all female members are

literate in presented in Table 6-3. Nearly total literacy has been achieved among Terkanahalli women in brahminical (Lingayat, Havik Brahmin, and Sonar/Shet) households. Economically progressive Namadhari Naik and Muslim households display intermediate levels of total female literacy, while total household female literacy is low among all other castes.

Table 6-3. Distribution of households in which all females are literate, by caste

Caste	**Households in Which All Females are Literate**, n=122
Havik Brahmin	41 of 42 (98 percent)
Lingayat	2 of 2 (100 percent)
Sonar/Shet	8 of 9 (89 percent)
Namadhari Naik	18 of 29 (62 percent)
Badagi	1 of 5 (20 percent)
Muslim	7 of 11 (64 percent)
Poojari Naik	0 of 4* (0 percent)
Kodiya	0 of 3* (0 percent)
Patgar	0 of 1* (0 percent)
Maratha	2 of 7 (29 percent)
Vokkaliga Gowda	3 of 7 (43 percent)
Moger	0 of 2* (0 percent)

*Represents all households in the survey area

Table 6-4 lists households in which all females or all males are illiterate, by caste. All brahminical households surveyed are,

to some extent, literate. All other caste households surveyed reported total female illiteracy more often than total male illiteracy.

Table 6-4. Distribution of households in which all females or all males are illiterate, by caste

Caste, households sampled	**Females**	**Males**
Havik Brahmin, n=42	0	0
Lingayat, n=2	0	0
Sonar/Shet, n=9	0	0
Namadhari Naik, n=29	7	1
Badagi, n=5	2	1
Muslim, n=11	4	2
Poojari Naik, n=4*	2	0
Kodiya, n=3*	3	0
Patgar, n=1*	1	0
Maratha, n=7	5	1
Vokkaliga Gowda, n=7	4	0
Moger, n=2*	2	0
Totals	**30**	**5**

*Represents all households in the survey area

Land Ownership, Employment, and Land Encroachment

Ownership of *Areca* nut/spice gardens has been the historical prerogative of Havik Brahmins in Kanara District. Lopping rights in *betta* forests are a state-sanctioned privilege associated with

spice garden ownership. Increasing regional and international demand for *Areca* nut continues to boost profits from these gardens. In Terkanahalli, and throughout Kanara, lands that were formerly considered unsuitable for *Areca* culture are now being converted to gardens wherever possible. Namadhari Naik, Sonar/Shet, and Muslim groups are now taking up *Areca* culture.

Table 6-5. Land ownership and forest use rights by caste family

Caste, n=122	**Own Paddy** (rice fields)	**Own *Arecanut*** (spice gardens)	**Have *Betta* Forest Use Rights**
Havik Brahmin, n=42	37	37	31
Lingayat, n=2	0	0	0
Sonar/Shet, n=9	5	1	0
Namadhari Naik, n=29	20	4	1
Badagi, n=5	2	0	0
Muslim, n=11	1	1	0
Poojari Naik, n=4	0	0	0
Kodiya, n=3	0	0	0
Patgar, n=1	1	0	0
Maratha, n=7	2	0	0
Vokkaliga Gowda, n=7	6	0	0
Moger, n=2	0	0	0
Totals	**74**	**43**	**32**

Paddy ownership is a another sign of economic welfare, and is becoming more common among non-brahminical caste groups. Table

6-5 provides summary land ownership and *betta* rights information by caste family group. Survey responses are based on family, not individual, land holdings.

Table 6-6. Distribution of employment by caste

Caste, n=122	**Land-owning Farmer**	**Farmer on Leased Land**	**Unskilled Laborer**	**Other**
Havik Brahmin, n=42	39	0	1	2, priestess
Lingayat, n=2	2	0	0	0
Sonar/Shet, n=9	5	0	4	0
Namdhari Naik, n=29	15	1	12	1, retired
Badagi, n=5	2	0	2	1, carpenter
Muslim, n=11	0	1	7	3, merchant
Poojari Naik, n=4	0	0	4	0
Kodiya, n=3	0	0	2	1, barber
Patgar, n=1	1	0	0	0
Maratha, n=7	1	1	5	0
V. Gowda, n=7	1	5	1	0
Moger, n=2	0	0	2	0
Totals	**66**	**8**	**40**	**8**

Table 6-6 summarizes informant employment information by caste. Land-owning farmers are primarily Brahminical, but include half of all Namadhari Naik informants. Other non-brahminical informants are unskilled laborers, except Vokkaliga Gowdas, most of whom farm leased land. Those who classify

themselves as unskilled laborers, or coolies, work either for land-owning farmers, in forest department tree nurseries, or in Sirsi Town. Forty-six percent of women reported themselves to be unskilled laborers, versus 14 percent of male informants. Most female laborers have seasonal or non-permanent jobs in local tree nurseries, jobs performed almost entirely by women. Seedling outplanting work during monsoon rains is also done by women.

Table 6-7. Distribution of unskilled laborers, by caste and gender

Caste	**Females**, n=85	**Males**, n=37
Havik Brahmin	1 of 24	0 of 18
Lingayat	0 of 2	none interviewed
Sonar/Shet	4 of 7	0 of 2
Namadhari Naik	8 of 19	3 of 10
Badagi	2 of 5	none interviewed
Muslim	8 of 9	0 of 2
Poojari Naik	3 of 3	0 of 1
Kodiya	2 of 3	none interviewed
Patgar	0 of 1	none interviewed
Maratha	5 of 5	0 of 2
Vokkaliga Gowda	6 of 7	none interviewed
Moger	none interviewed	2 of 2
Totals	**39 of 85** (46 percent)	**5 of 37** (14 percent)

Only five of 33 (15 percent) brahminical female informants were unskilled laborers. In contrast, 34 of 52 (65 percent) of all non-brahminical women informants were unskilled laborers. Table 6-7 indicates the distribution of unskilled laborers by caste and gender.

Table 6-8. Distribution of Gaonthana use and land encroachment, by caste

Caste, n=122	**House Located on Gaonthana Land**	**House Located on Encroached Land**	**Agricultural Encroachment of Forest Lands**
Havik Brahmin, n=42	22	2	2
Lingayat, n=2	0	2	0
Sonar/Shet, n=9	7	0	0
Namadhari Naik, n=29	16	8	7
Badagi, n=5	3	1	0
Muslim, n=11	0	10	0
Poojari Naik, n=4	1	3	1
Kodiya, n=3	3	0	0
Patgar, n=1	1	0	0
Maratha, n=7	2	5	1
Vokkaliga Gowda, n=7	0	1	1
Moger, n=2	0	2	0
Totals	**55** (45 percent)	**34** (28 percent)	**12** (10 percent)

Village land, gaonthana, is mentioned in British land settlement records by the early 19th century (Bombay Gazetteer

1882). Gaonthana is administered by local village governments as sites for schools and other public buildings, festival venues, sacred places, and as homesites for underprivileged families and caste groups. As rural populations have grown, encroachment of gaonthana by land-strapped homesteaders has become commonplace. Gaonthana encroachment is not limited to the poor, but commonly practiced by most caste groups. Encroachment has also extended into other public land, including forest lands, as agricultural land has become scarce (see Table 6-8).

House and Roof Type

Most survey informants have unfired, mud walled dwellings and fired clay tile roofs. The wealthiest 20 percent of Havik Brahmins have laterite block houses, though only three of these have corrugated metal roofs. Muslims live near Banvasi Road and purchase fired bricks from non-local sources to build their homes. The poorest 25 percent of Namadhari Naiks, Vokkaliga Gowdas, Poojari Naiks, Marathas, Muslims, and Mogers have thatched roof houses. Wealthy families have larger homes, stables, and connecting courtyards, but construct these from mud walls and clay roof tiles.

Income

Informants reported their annual household income in a categorical manner, by assignment to one of five intervals.

Table 6-9. Distribution of annual household income in Indian Rupees, by caste

Caste, n=122	**<2000**	**2000-5000**	**5000-10,000**	**10,000-20,000**	**>20,000**
H. Brahmin, n=42	0	2	7	11	22
Lingayat, n=2	0	1	1	0	0
Sonar/Shet, n=9	0	2	5	2	0
N. Naik, n=29	3	9	11	5	1
Badagi, n=5	0	2	2	1	0
Muslim, n=11	1	5	5	0	0
P. Naik, n=4	0	2	2	0	0
Kodiya, n=3	2	0	1	0	0
Patgar, n=1	0	0	1	0	0
Maratha, n=7	0	6	1	0	0
V. Gowda, n=7	0	1	5	1	0
Moger, n=2	0	1	1	0	0
Totals	**6**	**31**	**42**	**20**	**23**

Table 6-9 presents the distribution of these household income intervals by caste. Annual income greater than 10,000 Indian Rupees is almost entirely restricted to brahminical and Manadhari Naik castes. One US dollar equalled 22.50 Indian Rupees in mid-1992.

Livestock Ownership

Domestic animals include buffaloes, oxen, cows, and goats. Table 6-10 presents the average number of livestock owned per caste household for each of these domesticates.

Table 6-10. Distribution of average number of 4 types of livestock, by caste family

Caste	Oxen	Cows	Buffaloes	Goats
Havik Brahmin, n=42	0.52	2.43	2.24	0.0
Lingayat, n=2	0.5	0.0	1.0	0.0
Sonar/Shet, n=9	1.3	0.9	0.6	0.2
Namadhari Naik, n=29	1.72	1.48	1.38	1.03
Badagi, n=5	0.4	3.2	0.6	0.0
Muslim, n=11	0.18	0.0	0.18	0.0
Poojari Naik, n=4	0.0	0.25	0.0	0.0
Kodiya, n=3	0.0	2.0	0.0	0.0
Patgar, n=1	1.0	0.0	1.0	0.0
Maratha, n=7	0.71	1.0	0.0	0.0
Vokkaliga Gowda, n=7	1.28	0.86	0.57	0.0
Moger, n=2	0.0	0.0	0.0	0.0

Brahminical and Namadhari Naik families maintain relatively large numbers of oxen, cows, and buffaloes. Among other castes Vokkaliga Gowdas maintain modest numbers of these three domesticates, Badagis and Kodiyas own primarily cows, and Marathas own modest numbers of cows and oxen.

Collection of Non-Timber Forest Products

Informants prioritized the most important products they personally collect from neighboring forests, the season of collection, and the forest type where collecting activities occur. Products most often mentioned include: fuelwood, green

leaves (fodder), dry leaves (garden mulch), fruits, mushrooms, bamboo shoots, and fiber. These seven product classes represent an incomplete listing of forest products collected locally. Informants also mentioned gums, resins, honey, medicinal plants, and timber species used in tool making and house construction. The follow-up survey includes information about these important but lesser-mentioned products. Informants confirmed that all they collect is for their personal use or sold locally. No forest products are marketed outside of Terkanahalli to generate supplemental income. Table 6-11 provides a summary of the number of times priority forest products were mentioned, month(s) when they are collected, and forest types where they are collected, by caste group. Fuelwood collection was mentioned most often by informants from all castes, except Muslims, who usually purchase fuelwood from forest department depots. Havik Brahmins and Namadhari Naiks emphasized dry leaf and green leaf collection, to fertilize their gardens/fields and to feed their livestock. Non-brahminical informants allocate their collection effort to a wide variety of products. This is also true of Sonars/Shets, who earn more modest family incomes than do Havik Brahmins. Forest product collection effort is most intense at the end of the dry season (April-May) - a time of scarcity, but when household labor resources are abundant. Minor forests were cited as the most important product collection areas by all castes, except: Havik Brahmins, who have access to *betta* forests; and Kodiyas, who live adjacent to a reserved forest.

Table 6-11. Priority forest products, month(s) collected, forest type where collected, and number of times mentioned, by caste

Caste	**Priority Items** (times mentioned)	**Month(s) Collected**	**Where Collected** (times mentioned)
H. Brahmin, n=42	Fuelwood (33) Dry Leaves (30) Green Leaves (26) Fruits (9)	May Jan-May Jul-Aug Feb-May	*Betta* Forests (33), Minor Forests (7), & No Collection (2)
Lingayat, n=2	Fuelwood (2) Green Leaves (1)	May Jun-Aug	Minor Forests (2)
Sonar/Shet, n=9	Fuelwood (9) Mushrooms (3) Green Leaves (2) Bamboo Shoots (2) Fiber (1) Fruits (1)	Apr-May Aug Jul-Aug Jun-Jul May May	Minor Forests (9)
N. Naik, n=29	Fuelwood (29) Fiber (11) Dry Leaves (10) Green Leaves (13) Mushrooms (9) Fruits (13) Bamboo Shoots (3)	Mar-May May Apr-May Jul-Sept Jul-Aug Apr-May May-Jun	Minor Forests (20), Reserve Forests (8), & *Betta* Forests (1)

Table 6-11--continued

Caste	**Priority Items** (times mentioned)	**Month(s) Collected**	**Where Collected** (times mentioned)
Badagi, n=5	Fuelwood (5) Fruits (4) Mushrooms (3) Fiber (3)	May Dec-May Jun-Aug All Year	Reserve Forests (4), & Minor Forests (1)
Muslim, n=11	Fuelwood (1) Green Leaves (1) Dry Leaves (1)	May Jun-Sept May	Minor Forests (1) No Collection (10)
P. Naik, n=4	Fuelwood (4) Fruits (2) Green Leaves (1) Dry Leaves (1) Mushrooms (1) Bamboo Shoots(1) Fiber (1)	Apr-May Dec-May Jul-Aug Apr-May Jun May All Year	Minor Forests (4)
Kodiya, n=3	Fuelwood (3) Dry Leaves (1) Fruits (2)	May Dec Apr-May	Reserve Forests (3)
Patgar, n=1	Fuelwood (1) Fruits (1)	May Apr	Minor Forests (1)

Table 6-11--continued

Caste	**Priority Items** (times mentioned)	**Month(s) Collected**	**Where Collected** (times mentioned)
Maratha, n=7	Fuelwood (7)	May	Minor Forests (7)
	Green Leaves (4)	Jun-Sept	
	Dry Leaves (1)	Feb-May	
	Fruits (1)	Dec-May	
	Bamboo Shoots (1)	Jun	
	Fiber (1)	All Year	
V. Gowda, n=7	Fuelwood (7)	May	Minor Forests (5),
	Dry Leaves (5)	May	Reserve Forests (1),
	Green Leaves (4)	Jun-Aug	& Plantations (1)
	Mushrooms (3)	Aug	
	Fruits (1)	Dec-May	
Moger, n=2	Fuelwood (2)	May	Minor Forests (2)
	Green Leaves (1)	Jun	
	Dry Leaves (1)	May	
	Fruits (1)	May	

Both women and men participate in harvesting forest products. Eight-six percent of both female and male informants collect fuelwood. A greater percentage of men than women informants lop trees and collect leaf mulch. Numbers and percentages of female and male informants that collect priority forest products are presented in Table 6-12.

Table 6-12. Numbers and percentage of female and male informants that collect priority forest products

Priority Forest Products	Female Collectors, n=85	Male Collectors, n=37
Fuelwood	73 (86 percent)	32 (86 percent)
Green Leaves	28 (33 percent)	25 (67 percent)
Dry Leaves	31 (36 percent)	19 (51 percent)
Fruits	24 (28 percent)	11 (30 percent)
Mushrooms	17 (20 percent)	2 (5 percent)
Fiber	12 (14 percent)	7 (19 percent)
Bamboo Shoots	5 (6 percent)	2 (5 percent)

Fuelwood

Males and females of all castes share in fuelwood collection (see Table 6-13), with the exception of Muslim women. Ten female informants did state that it is usually women who go to the forest to collect firewood. Fuelwood collection occurs particularly during April and May, the final 2 months of the dry season.

Table 6-13. Fuelwood collection by gender and caste

Caste Grouping	Female Collectors	Male Collectors
Muslim	0 of 9 (0 percent)	1 of 2 (50 percent)
All Other Caste Groups	73 of 76 (96 percent)	31 of 35 (89 percent)

Annual fuelwood collection for individual households was reported in cartload equivalents - 1 cartload equalling 400 kg. Average

annual fuelwood collection per household, by caste group, is shown in Table 6-14. Twenty-one of 42 Havik Brahmin households use biogas generated from domestic animal waste to supplement their fuelwood use requirements.

Table 6-14. Average annual fuelwood collection in kilograms and cartloads, by caste household

Caste Household	**Kilograms per Family**
Havik Brahmin, n=42	1600 (4 cart loads)
Lingayat, n=2	1600 (4 cart loads)
Shet, n=9	2400 (6 cart loads)
Namadhari Naik, n=29	3280 (8.2 cart loads)
Badagi, n=5	2080 (5.2 cart loads)
Muslim, n=11	200 (<1 cart load)
Poojari Naik, n=4	2000 (5 cart loads)
Kodiya, n=3	2920 (7.3 cart loads)
Patgar, n=1	2400 (6 cart loads)
Maratha, n=7	2800 (7 cart loads)
Vokkaliga Gowda, n=7	2280 (5.7 cart loads)
Moger, n=2	2800 (7 cart loads)

Leaves

Green leaves are lopped from woody perennials for fodder, and are also lopped from *betta* forest trees and dried before collection as mulch. The most popular fodder-producing trees species in Terkanahalli are: *Dillenia pentagyna*, *Grewia tiliaefolia*, *Ficus Glomerata*, *Pterocarpus marsupium*, and *Pothos*

scandens. Livestock-owning Havik Brahmins, Namadhari Naiks, and Vokkaliga Gowdas allocate considerable effort to lopping leaves. Badagis and Kodiyas, many of whom own cows, did not report lopping activity. They purchase fodder from others and/or collect herbaceous fodder. Lingayats and the Patgar did not report how they acquire leaf fodder for their oxen and buffaloes. Green leaf lopping by caste and gender is shown in Table 6-15.

Table 6-15. Collection of green leaf fodder, by caste and gender

Caste	**Female Collectors**	**Male Collectors**
Havik Brahmin, f=24, m=18	14 (58 percent)	12 (67 percent)
Shet, f=7, m=2	1	1
Namadhari Naik, f=19, m=10	6 (32 percent)	7 (70 percent)
Muslim, f=9, m=2	0	1
Poojari Naik, f=3, m=1	0	1
Maratha, f=5, m=2	2	2
Vokkaliga Gowda, f=7	4 (57 percent)	none interviewed
Moger, m=2	none interviewed	1

Annual green leaf collection for individual households was reported in headload equivalents - 1 headload equalling 25 kg. Table 6-16 shows average annual green leaf collection per household for the two major leaf collecting caste groups - Havik Brahmin and Namadhari Naik.

Table 6-16. Average annual green leaf collection in kilograms, for the two major leaf-collecting castes

Caste Household	**Kilograms/Household**
Havik Brahmin, n=42	3437.5 (137.5 headloads)
Namadhari Naik, n=29	1562.5 (62.5 headloads)

Dry leaves are collected on the forest floor and applied to spice gardens and agricultural fields as green manure and mulch. Havik Brahmins apply leaf mulch primarily to spice gardens, while Namadhari Naiks and Vokkaliga Gowdas apply mulch to agricultural fields. The most popular leaf manure-producing tree species are: *Careya arborea*, *Terminalia tomentosa*, *Terminalia paniculata*, *Pterocarpus marsupium*, *Dillenia pentagyna*, and *Buchanania latifolia*. Dry leaf collection by gender and caste is presented in Table 6-17.

Table 6-17. Dry leaf collection, by caste and gender

Caste	**Female Collectors**	**Male Collectors**
Havik Brahmin, f=24, m=18	18 (75 percent)	12 (67 percent)
Namadhari Naik, f=19, m=10	6 (32 percent)	4 (40 percent)
Muslim, f=9, m=2	0	1
Poojari Naik, f=3, m=1	0	1
Kodiya, f=3, m=0	1	none interviewed
Maratha, f=5, m=2	1	0
Vokkaliga Gowda, f=7, m=0	5 (71 percent)	none interviewed
Moger, f=0, m=2	none interviewed	1

Annual dry leaf collection for individual households was reported in headload equivalents - 1 headload equalling 25 kg. (see Table 6-18), for the two major leaf collecting caste groups.

Table 6-18. Average annual dry leaf collection in kilograms, for the two major leaf-collecting castes

Caste Household	**Kilograms/Household**
Havik Brahmin, n=42	5832.5 (233.3 headloads)
Namadhari Naik, n=29	1530 (61.2 headloads)

Fruits

Table 6-19 indicates the number of times informants from different castes mentioned, unsolicited, that they collect six

Table 6-19. Collection of six popular species of fruit, by caste (times mentioned)

Caste	**Mango**	**Jack**	**Wataekai**	**Acacia**	**Soapnut**	**Mangosteen**
Havik Brahmin, n=42	1	1	4	0	7	5
Sonar/Shet, n=9	1	1	1	0	0	0
Namdhari Naik, n=29	3	3	2	1	1	1
Badagi, n=5	3	4	3	2		1
Kodiya, n=3	2	2	1	1	0	0
Poojari Naik, n=4	1	0	0	0	0	1
V. Gowda, n=7	1	1	1	1	0	1
Maratha, n=7	0	0	0	0	1	0
Total	**12**	**12**	**12**	**5**	**9**	**9**

species of fruit: mango (*Mangifera indica*), jack (*Artocarpus integrifolia*), wataekai (*Artocarpus lacucha*), Acacia (*Acacia coccina*), soapnut (*Sapindus emerginata*), and mangosteen (*Garcinia indica*). These are some of the most popular local forest fruits. They are seasonally collected by men and women informants from eight caste groups.

Mushrooms

Two groups of edible funji are collected locally, dark and light button mushrooms. Both fruit during monsoon rains, and are primarily collected by Namadhari Naik and poorer caste women (see Table 6-20). Vokkaliga Gowda women reported that they each collect approximately 1 kg. of mushrooms each rainy season. Though no informants supplement their income from mushroom sales, there is a market for them in Sirsi Town. Entrepreneurs have begun commercial cultivation of non-wild mushrooms in Kanara District.

Table 6-20. Mushroom Collection, by caste (times mentioned)

Caste	**Times Mentioned**
Namadhari Naik	7
Badagi	2
Vokkaliga Gowda	1
Poojari Naik	1
Sonar/Shet	1

Date Palm

Besides consuming *Phoenix silvestris* fruits, poor caste groups use date palm fiber to weave 'chape' mats and to make whisk brooms. Table 6-21 indicates those caste groups that mentioned they collect date palm products.

Table 6-21. Date palm product collection, by caste (times mentioned)

Caste	Times Mentioned
Namadhari Naik	11
Badagi	2
Poojari Naik	2
Patagar	1
Sonar/Shet	1
Maratha	1
Moger	1

Disappearing Forest Products

Table 6-22 lists the 10 products most commonly mentioned by informants as having become scarce or locally extinct. Raw nuts of *Artocarpus lacucha* are dried for use as a sour spice in cooking. *Acacia coccina* seeds are crushed for use as shampoo/soap in bathing. *Sapindus indica* seeds are also a source of shampoo/soap. Havik Brahmins most often mentioned the local disappearance of wild honey (19 times), *Artocarpus lacucha* (16 times), *Acacia coccina* (14 times), and *Sapindus indica* (seven times) from surrounding forests. Poorer caste groups uniformly mentioned all of the products listed in Table 6-22.

Table 6-22. Increasingly scarce forest products (times mentioned)

Forest Product	**Times Mentioned**
Artocarpus lacucha	38
Wild Honey	35
Acacia coccinna	30
Garcinia indica	22
Sapindus indica	12
Construction Timber	12
Bamboo	11
Mushrooms	10
Artocarpus integrifolia	6
Mangifera indica	4

When asked why these 10 desired products have become scarce or extinct in local forests, illegal lopping and felling of trees was prominently cited (84 of 90 times). Table 6-23 summarizes local beliefs about why these products have become scarce. A 'not applicable' response was given for informants who do not themselves collect these 10 forest products.

Table 6-23. Reasons cited why 10 forest products are becoming locally scarce, by caste (times mentioned)

Caste	Scarce, Felling	Extinct, Felling	Lack of Vigilence of Forest Guards	Soil too Dry	Not Applicable
Havik Brahmin, n=42	5	27	1	0	9
Lingayat, n=2	0	1	0	0	1
Sonar/Shet, n=9	2	3	0	2	2
Namadhari Naik, n=29	11	13	0	1	4
Badagi, n=5	3	1	0	0	1
Muslim, n=11	0	4	0	1	6
Poojari Naik, n=4	1	2	0	0	1
Kodiya, n=3	0	0	0	1	2
Patgar, n=1	0	1	0	0	0
Maratha, n=7	2	4	0	0	1
Vokkaliga Gowda, n=7	1	1	0	0	5
Moger, n=2	0	2	0	0	0
Totals, n=122	**25**	**59**	**1**	**5**	**32**

Local Perceptions of Multiple Species Plantations (MSPs)

Only nine of 122 informants indicated that MSPs are of any benefit to the local community. Of these nine, five Namadhari Naik women and a Poojari Naik woman are seasonally employed in forest department tree nurseries. Two informants spread *Casuarina* and *Acacia* leaves from plantations on their gardens to intentionally suppress weed growth. One informant felt that MSPs decreased local timber theft, since no harvestable timber can be

found in young plantations. Fifty-eight of 122 (48 percent) informants reported that, to date, they perceive no disadvantages associated with MSPs.

Sixty-four (52 percent) informants reported four primary disadvantages of MSPs to local communities. Two informants felt that only the state government benefits from expansion of MSPs. Reported opinions about MSPs were uniformly distributed across all non-Muslim castes and gender lines, and are listed in Table 6-24.

Table 6-24. Local opinions about MSPs (times mentioned)

Opinion about MSPs	**Times Mentioned**
Positive benefits	9
No Disadvantages	58
Disappearance of Fodder Resources	39
Fuelwood Collection Restrictions	10
Diminished Groundwater Resources	10
Loss of Medicinal Resources	5

Informants were then asked if MSPs are an improvement over the minor forests that they are replacing, and on what basis. Not one informant reported MSPs to be an improvement over minor forest areas. Twenty informants did feel that MSPs have had no net impact on the community, either positive or negative. This group consisted of 10 Muslims, six Havik Brahmins, and four Badagis. Many Muslims do not personally collect forest products, while the other two groups have collection privileges in *betta* or

private forested (*malki*) lands. Lost medicinal resources were reported exclusively by Havik Brahmins. Other negative comparisons of MSPs to minor forests were uniformly distributed across caste and gender, and are shown in Table 6-25.

Table 6-25. Local opinions about MSPs versus minor forests (times mentioned)

Opinion about MSPs versus Minor Forests	**Times Mentioned**
No Impact, Either Positive or Negative	20
Loss of Fodder Resources, Leaves & Grasses	30
Fuelwood Collection Restrictions	25
Loss of Green Leaf Manure/Mulch Resources	22
Unspecified Loss of Multiple Uses	17
Loss of Medicinal Resources	8

Perceived Need for Local Forests

Informants were asked if there is an increasing need for forests of all types in and around Terkanahalli Village and, if so, why. Everyone agreed that forests are a vital community resource, but reasons for this varied. A few informants stressed specific products derived from forests, such as fuelwood, fodder, and medicines. A majority, however, stressed broader environmental attributes of forest systems, particularly those associated with soil fertility and agricultural productivity. Responses were not caste or gender-specific, and are listed in Table 6-26.

Table 6-26. Perceptions about the utility of local forests (times mentioned)

Perceptions About the Utility of Local Forests	Times Mentioned
Increase Soil moisture & Extend Growing Season	32
Improve Local Agricultural Productivity	21
Attenuate Climatic Extremes & Pollution	18
Provide Unspecified Multiple Use Benefits	17
Source of Fuelwood	15
Source of Leaves for Fodder & Green Manure	8
Source of Lumber for Tool Making	6
Source of Medicinal Resources	5

Locally Popular Tree Species

When asked about preferred types of trees to be included in future reforestation programs, native multiple-use species were mentioned most often (93 times), followed by native timber species (24 times), and native fruit trees (three times). Specific tree species that informants most frequently requested for inclusion in future reforestation programs are listed in Table 6-27, along with their primary use(s). Eight or more of these species are already among those routinely planted in MSPs. However, 30 informants felt that the growth of native tree species was discouraged in MSPs. Five individuals felt that native species should account for fully two-thirds of all tree plantings in MSPs. *Casuarina* and *Acacia* trees presently comprise 65-80 percent of all plantings in MSPs.

Table 6-27. Tree species most requested for inclusion in future reforestation programs, and their use

Tree Species	**Times Requested**	**Primary Uses(s)**
Terminalia tomentosa	56	Green Manure/Mulch, Lumber
Terminalia paniculata	41	Green Manure/Mulch, Lumber
Xylia xylocarpa	33	Insect Resistent Lumber, Combustible Seed Pods
Pterocarpus marsupium	21	Fodder, Lumber, Coloring Agent
Dalbergia latifolia	11	Valuable Lumber
Artocarpus heterphylla	9	Lumber, Fruit
Lagerstroemia lanceolata	9	Lumber, Green Manure/Mulch
Careya arborea	7	Plough Making, Garden Mulch
Mangifera indica	7	Fruit
Tectona grandis	7	Lumber
Santalum album	6	Incense Making
Syzygium cumini	5	Fruit, Veterinary Medicine
Anacardium occidentale	3	Fruit, Oil Insecticide
Vitex ultissima	2	Veterinary Medicine

Informants made unsolicited suggestions about how to promote regeneration of these and other native tree species. Fencing/trenching of all remaining minor forests to facilitate natural regeneration was mentioned 32 times. Planting of gaps in fenced minor forests with under-represented native species (enrichment) was mentioned 11 times. These suggestions were not

caste or gender specific. However, six Muslims and four Vokkaliga Gowdas supported expansion of MSPs without changes, to increase fuelwood supplies.

Suggested Future Reforestation Methodologies

The baseline survey concluded by soliciting informant opinion about siting of future reforestation programs (see Table

Table 6-28. Local recommendations for siting of future reforestation programs (times mentioned), by caste

Caste	Private Land	Forest Dept Land	Village Land	Betta Land	Not Specified
Havik Brahmin, n=42	2	28	0	1	11
Lingayat, n=2	0	1	0	0	1
Sonar/Shet, n=9	3	3	2	0	1
Namadhari Naik, n=29	2	22	2	0	3
Badagi, n=5	0	3	1	1	0
Muslim, n=11	1	9	0	0	1
Poojari Naik, n=4	0	4	0	0	0
Kodiya, n=3	0	2	1	0	0
Patgar, n=1	0	1	0	0	0
Maratha, n=7	0	4	0	0	3
Vokkaliga Gowda, n=7	0	6	0	0	1
Moger, n=2	0	1	0	0	1
Totals, n=122	**8**	**84**	**6**	**2**	**22**

6-28), and recommended implementation strategies (see Table 6-29). Eighty-four of 122 informants felt that reforestation programs should continue to be implemented on forest department lands. Table 6-29 indicates that 65 of 122 informants desired a continuation of forest department-sponsored tree planting programs. However, 31 of these 65 informants independently suggested that joint forest planting and management agreements be adopted henceforth.

Table 6-29. Local recommendations for implementation strategy of future reforestation programs (times mentioned), by caste

Caste	**Private**	**Government Sponsored**	**Village Cooperation**	**NGO**	**Not Specified**
Havik Brahmin, n=42	3	19	15	5	0
Lingayat, n=2	0	1	1	0	0
Sonar/Shet, n=9	3	3	3	0	0
Namadhari Naik, n=29	2	16	10	1	0
Badagi, n=5	0	4	1	0	0
Muslim, n=11	0	10	1	0	0
Poojari Naik, n=4	0	2	2	0	0
Kodiya, n=3	0	2	0	1	0
Patgar, n=1	0	0	1	0	0
Maratha, n=7	0	4	1	1	1
Vokkaliga Gowda, n=7	0	4	3	0	0
Moger, n=2	0	0	1	1	0
Totals, n=122	**8**	**65**	**39**	**9**	**1**

Joint management arrangements, as defined by informants, imply local responsibility for protection of replanted forests in exchange for limited tenure over non-timber resources. Outright leasing of forest tracts to individuals and families was mentioned five times.

Reforestation through private initiative was mentioned by eight individuals, all of whom own forest land (*malki bena*). Non-government organization (NGO) sponsorship of reforestation programs has never occurred in Terkanahalli, and was rarely suggested. Thirty-nine of those interviewed felt that independent village cooperative reforestation schemes should be initiated. Twelve Havik Brahmin women suggested that village women's societies (Mahila Mandals) were capable of carrying out cooperative tree planting programs.

CHAPTER 7
THE COMMUNITY FOREST RESOURCE STUDY: THE FOREST RESOURCE USE SURVEY

Introduction

When the baseline survey was completed, a more detailed forest resource use survey was administered. The latter survey focuses on informants' knowledge of forest plants, and their opinions about the plants they recognize. If properly constructed, a detailed survey may reveal informant use of both existing forest areas and the Multiple Species Plantations (MSPs) that are now replacing them. This line of inquiry can identify the extent of opportunities gained or lost when MSPs spring up on minor forest land next to forest-dependent villages.

Thirty-seven survey forest resource use survey informants were randomly selected from the sample of 122 that had participated in the prior baseline survey. This second survey measures the competence of these Terkanahalli people with respect to identification and use of 65 species of forest plants. This survey also assesses the effect of (MSP) programs on women's and men's reported use of forest resources among Havik Brahmins, as well as 11 less populous castes in the forest products use survey. Finally, the survey explores differences in knowledge

and reported use of forest resources based on informant age classes of 10-year intervals.

Forest Products Use Survey Data Collection

While conducting silvicultural research, I collected plant specimens commonly associated with minor forest environments. Forest department field officers and local people helped in plant identification. The collection included 65 species (see Appendix B) having commonly recognized uses among village informants. For each of the 65 species, branches, vegetative buds, and whenever possible flowers and fruit were photographed several times. One 3" X 5" photograph of each species in the collection was selected for future use in the forest resource use survey. This photographic collection of forest plants was by no means comprehensive, but did include those species that villagers commonly mentioned they harvested for personal and family use. These 65 species became elements in a cognitive domain of locally used forest resources. The use of photographs to represent forest species was practical, since living material could not be maintained for use during the entire survey.

Presenting photographs for inspection, rather than flashcards with species names written on them, stimulated informants to reflect upon:

1) whether they indeed recognized a particular plant species;

2) the extent of their personal knowledge about the utility of each species; and

3) the kind of forest, or forest type, from which each familiar plant species could be obtained - all objects of my investigation.

After recording an informant's gender, caste, age, and hamlet of residence, field assistants asked each informant to sort the 65 plant photographs into piles six different times, following the survey questionnaire format (see Appendix C). This procedure is known as pile sorting (Borgatti 1992). In this survey, informant sorting was often guided by the use of pre-determined categories. Categorical scales help structure pile sorts, can be flexibly customized to the particular needs of researchers, and facilitate analysis of survey response data. The list below describes the series of pile sorts conducted, and the information content of each sort.

1. Informants selected photographs of recognized plant species from the sample of 65 plant photographs. This pile sort provides a relative measure of informant competence to correctly identify 65 forest plant species.

2. Informants assigned both a tally of uses and the primary use of each identified plant species. These responses provide a relative measure of informant knowledge about the versatility and use of each identified plant species (see Appendix D).

3. Informants assigned identified plant species to one of five categories, according to their perceived usefulness. This pile sort provides a relative measure of informant perception about the utility of each identified plant species.

4. Informants assigned identified plant species to one of five categories, according to how rare they were perceived to be. This pile sort provides a relative measure of informant perception of how often each identified plant species is encountered locally.

5. Informants selected those plant species that they had occasion to collect in minor forest areas. This pile sort provides a relative measure of the perceived

importance of minor forest areas as sources of forest plants and their products.

6. Informants ranked up to 10 plant species collected in minor forest areas, according to their perceived usefulness. They also estimated their annual collection of each plant species. This pile sort provides identification and ranking of the most important minor forest products collected by each informant.

Pile sorts five and six were then repeated, if appropriate, for *betta* forest, MSPs, and reserved forest areas. Pile sorts five and six provide a relative measure of the perceived importance of *betta* forest, MSPs, and reserved forest areas as sources of identified forest plant species and their products. Although attempted, pile sorts five and six were discontinued for MSPs and reserve forest areas, since no informant stated that s/he made significant collections of forest plants or their products in MSPs or reserve forests. Both of these forest types are patrolled by the KFD, and product collection from them is formally restricted. Only three informants mentioned that they collected identified forest plants in *betta* forests.

The second survey was administered from late May to early June 1992.

Forest Products Use Survey Data Analysis Tools and Procedures

The forest resource use survey data were analyzed according to informants' caste affiliation, gender, and age. Until the advent of inexpensive and user-friendly applications like *Anthropac 4.0* (Borgatti 1992), analysis of large field survey data sets was a difficult task. These data analysis tools are

particularly helpful to those who rely on surveys as a primary means of collecting information about people, their attitudes, and their environment. They provide analytical power in detecting patterns of knowledge and behavior within a sampled population.

Similarity Matrices

If an investigator wishes to evaluate whether individuals or groups of informants have similar attitudes across a domain of items (e.g. forest plant resources), s/he must first compile informant-by-survey item response data matrices - rows of data containing informants' judgments about each item in the domain of interest (Bernard 1988). These matrices are normally rectangular, being square when the number of informants exactly matches the number of items in the survey. Cell values of data matrices are then compared to generate symmetric, informant-by-informant similarity matrices. Mathematical coefficients in the cells of so-called aggregate similarity or aggregate proximity matrices numerically indicate how similar, or dissimilar, one informant's response profile is to each of the other informant's response profiles. Figure 7-1 is a similarity matrix of six female and six male Havik Brahmins' identification profiles of 65 minor forest plants. A diagonal line of 1.0 values crosses an aggregate similarity matrix from the top left corner to the bottom right corner of the matrix. This diagonal includes cells in which each response profile is compared with itself.

	1 F	2 F	3 F	4 F	5 F	6 F	7 M	8 M	9 M	10 M	11 M	12 M
1 F	1.00	0.72	0.70	0.59	0.77	0.68	0.74	0.57	0.78	0.80	0.38	0.72
2 F	0.72	1.00	0.74	0.59	0.75	0.72	0.84	0.59	0.91	0.81	0.39	0.82
3 F	0.70	0.74	1.00	0.64	0.80	0.73	0.73	0.55	0.67	0.71	0.52	0.71
4 F	0.59	0.59	0.64	1.00	0.63	0.65	0.54	0.52	0.53	0.53	0.53	0.60
5 F	0.77	0.75	0.80	0.63	1.00	0.75	0.75	0.60	0.74	0.75	0.46	0.75
6 F	0.68	0.72	0.73	0.65	0.75	1.00	0.68	0.54	0.71	0.72	0.45	0.69
7 M	0.74	0.84	0.73	0.54	0.75	0.68	1.00	0.58	0.82	0.75	0.39	0.81
8 M	0.57	0.59	0.55	0.52	0.60	0.54	0.58	1.00	0.54	0.57	0.33	0.61
9 M	0.78	0.91	0.67	0.53	0.74	0.71	0.82	0.54	1.00	0.88	0.38	0.80
10 M	0.80	0.81	0.71	0.53	0.75	0.72	0.75	0.57	0.88	1.00	0.41	0.76
11 M	0.38	0.39	0.52	0.53	0.46	0.45	0.39	0.33	0.38	0.41	1.00	0.44
12 M	0.72	0.82	0.71	0.60	0.75	0.69	0.81	0.61	0.80	0.76	0.44	1.00

Figure 7-1. A similarity matrix of plant identification, by gender, for Havik Brahmin informants

In this research, similarity matrices were generated for each response in the forest resource use survey, for all 37 informants with respect to caste, gender, and age class. These matrices were then input into hierarchical clustering and multidimensional scaling models to determine which informants tend to form clusters - to be similar or "hang together".

Hierarchical Clustering

Hierarchical clustering (HC) produces cluster diagrams that are agglomerative, i.e. they begin with many small clusters and gradually merge these into fewer and fewer bigger clusters. Johnson's hierarchical clustering (Borgatti 1992) is the most common clustering procedure, and is used in *Anthropac 4.0*. HC can be based on several algorithms, the most common being: 1) the *minimum* method, which agglomerates clusters according to the

greatest similarity between any item in one cluster and any item in another cluster; and 2) the *maximum* method, which agglomerates according to the least similarity between any item in one cluster and any item in another cluster. These methods produce similar hierarchies of clusters when data possess a clustered structure. The methods produce varying hierarchies as data become less structured, or non-clustered.

Multidimensional Scaling

Multidimensional scaling (MDS) is another analytical method that produces a visual representation of similarities among items in a domain. MDS mathematically squeezes items into a "least stress" optimal configuration within two-dimensional coordinate space. It does this by calculating Euclidean distances among all pairs of items that have been assigned arbitrary coordinates in n-dimensional space. The derived estimation matrix of similarities is then compared to the original input aggregate proximity data (Borgatti 1992). The greater the correspondence between these two matrices, the less the stress function. The more complex the relationship between items in a domain becomes, the more poorly MDS represents this relationship in two dimensions, and the greater the stress function (Stress values of less than 0.1 are considered acceptable in social science research (Borgatti 1992)). In other words, informants may tend to think about how items in a domain are related, or how similar they are, according to more than one criterion. This situation produces unusually large discrepancies in how informants position

ambiguous data items in two-dimensional space. To address this weakness of MDS, the number of dimensions may de increased to three or more, but the display clarity of two-dimensional scaling becomes sacrificed for an ever-decreasing reduction in stress. While MDS can indicate similarities in informant responses when they exist, it can also indicate ambiguous or confusing survey items - warranting their removal from subsequent surveys. If the stress function becomes too great, it becomes advisable to discard MDS as an analytical technique.

Consensus Analysis

Consensus analysis is based on the premise that agreement implies competence - that agreement among informants implies correct knowledge on their part. Stated otherwise, cultural consensus modeling permits a researcher to compare informant X response data matrices concerning elements in a cognitive domain to measure informant competence. Consensus analysis also provides a collective indication of the culturally defined truth about elements in a domain.

In formalized testing, an individual student's response profile is compared to that of the teacher's response profile on the same examination. By computing the proportion of student judgements that match the teacher's, a measure of that student's competence, or knowledge coefficient, can be derived. To formulate the probability of two individual students giving the same answer to specific questions, four potential outcomes must be considered:

1. Student A and Student B both know the correct answer(s);

2. Student A knows the correct answer while Student B guesses correctly;

3. Student B knows the correct answer while Student A guesses correctly;

4. Neither student knows the correct answer, but both guess the same answer - regardless of whether it is correct or incorrect.

When these four probabilities are summed, the probability that Students A and B give the same answer (mAB) is:

dAdB + dA(1-dB)/L + dB(1-dA)/L + (1-dA)(1-dB)/L , in which

dA = p(Student A knows)

dB = p(Student B knows)

(1-dA) = p(Student A does not know)

(1-dB) = p(Student B does not know)

L = number of alternative choices

1/L = p(a student guesses correctly).

This expression can be simplified to become mAB = (dAdB-1)/L. Thus, agreement between Student A and Student B is the product of their respective competencies (Borgatti 1992). Three assumptions must be met for this model to be robust:

1) there must be only one truly correct answer pertaining to each item in a domain;

2) there is independence among the judgements each student makes about items in a domain; and

3) there is homogeneity (or random selection) of the items in the domain that are selected for students to judge.

The utility of the consensus model is its predictive power about the correct answers to an examination, or a forest products survey, even when there is no teacher's answer key available for reference. By analyzing student-student examination response similarities (or informant-informant survey response similarities), both the level of each informant's knowledge and the culturally correct answers to survey questions can be deduced. Such a model also permits researchers to distinguish variation in responses at the sub-cultural level. In other words, consensus modeling can aid field researchers in identifying not only culturally defined correct answers, but also those subgroups within a culture that possess knowledge about a given cognitive domain, and those subgroups that do not.

Three assumptions analogous to those mentioned above must be met for consensus modeling to remain robust in the context of socio-cultural surveys:

1) variability in informant response is due to differences in amount of knowledge, not due to differences in cultural reality (i.e. all informants are members of the same comprehensive culture);

2) informants respond to survey questions independently of other informants, and do not give systematic responses (i.e. such as always answering "yes"); and

3) all items to be judged by informants are drawn from the same cognitive domain, and not mixed with items from any other domains.

As a final test for significant contrasts in informant response profiles, correlation analysis was performed on all knowledge coefficients produced by consensus analysis - using SPSS for Windows (version 6.1.2).

Forest Products Use Survey Results

Plant Identification

Multidimensional scaling, hierarchical clustering, and consensus analysis procedures were first used to compare informant response profiles for plant identification. Results provide a visual and mathematical basis for evaluating informant plant identification skills with respect to caste, gender, and age class.

The single cluster in the upper right-hand portion of Figure 7-2 indicates similarity across castes in identifying 65 plant species. Informants positioned beyond the cluster include: one Namadhari Naik (NN) - a 65 year old woman; one Poojari Naik (Po) - a 35 year old woman; one Kodiya (Ko) - a 45 year old man; and one Sonar/Shet (So) - a 27 year old woman. Figures 7-3 and 7-4 show the same plant identification response profiles with respect to gender and age class, respectively.

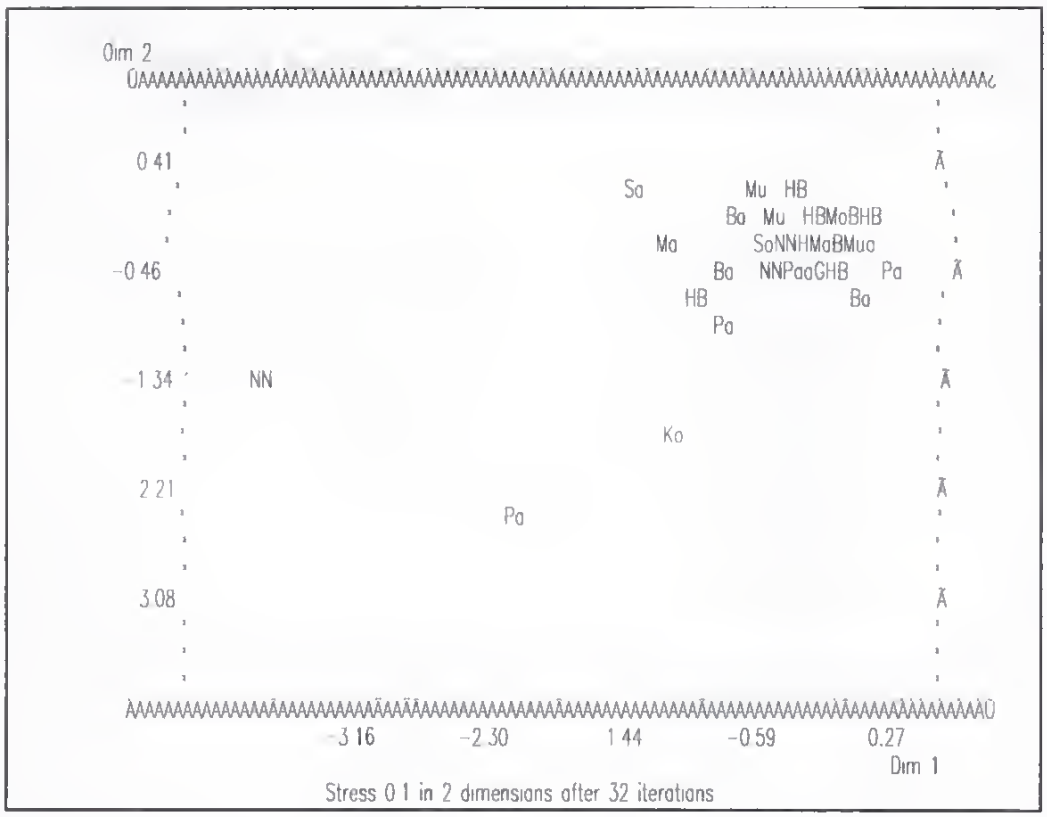


Figure 7-2. Plant identification, by caste, using multidimensional scaling

Figure 7-3 indicates internal similarity among males and females in plant identification, with the exception of the four informants mentioned above. Plant identification response profiles also appear similar across ten-year age classes (1:10-19; 2:20-29; 3:30-39, 4:40-49; 5:50-59; 6:60-69 and NA:age unknown) in Figure 7-4. In Summary, MDS analyses indicate general similarity among informants in their ability to identify 65 plant species from photographs.

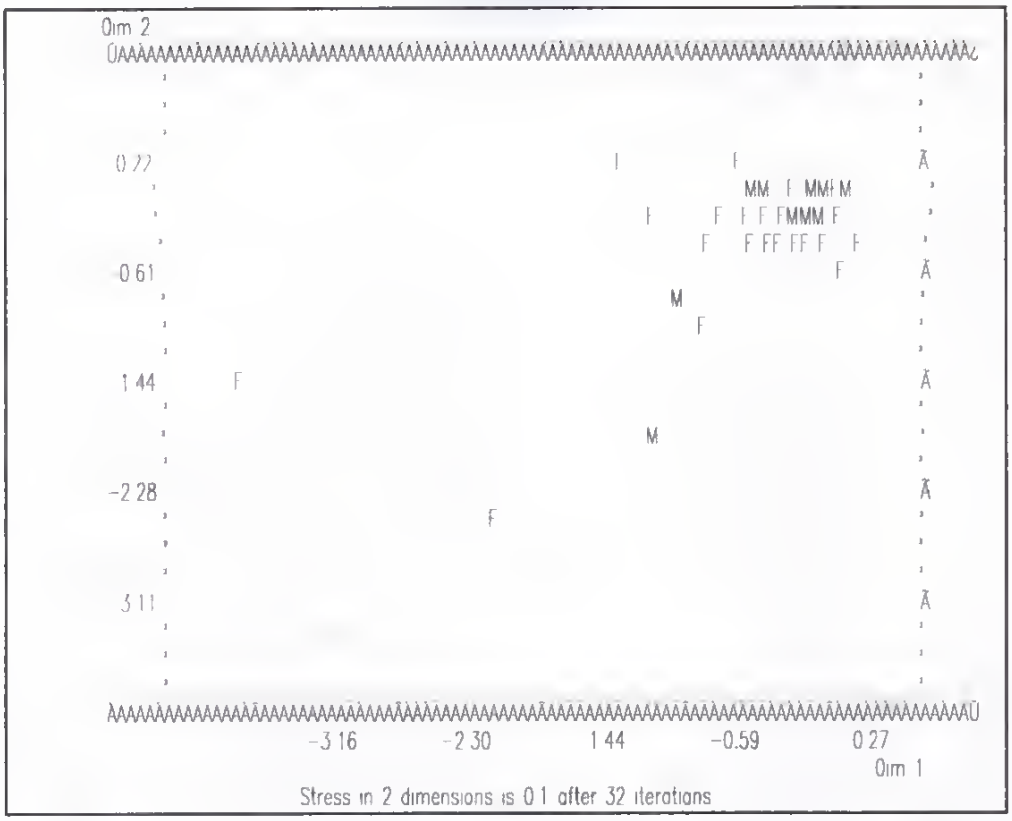


Figure 7-3. Plant identification, by gender, using multidimensional scaling

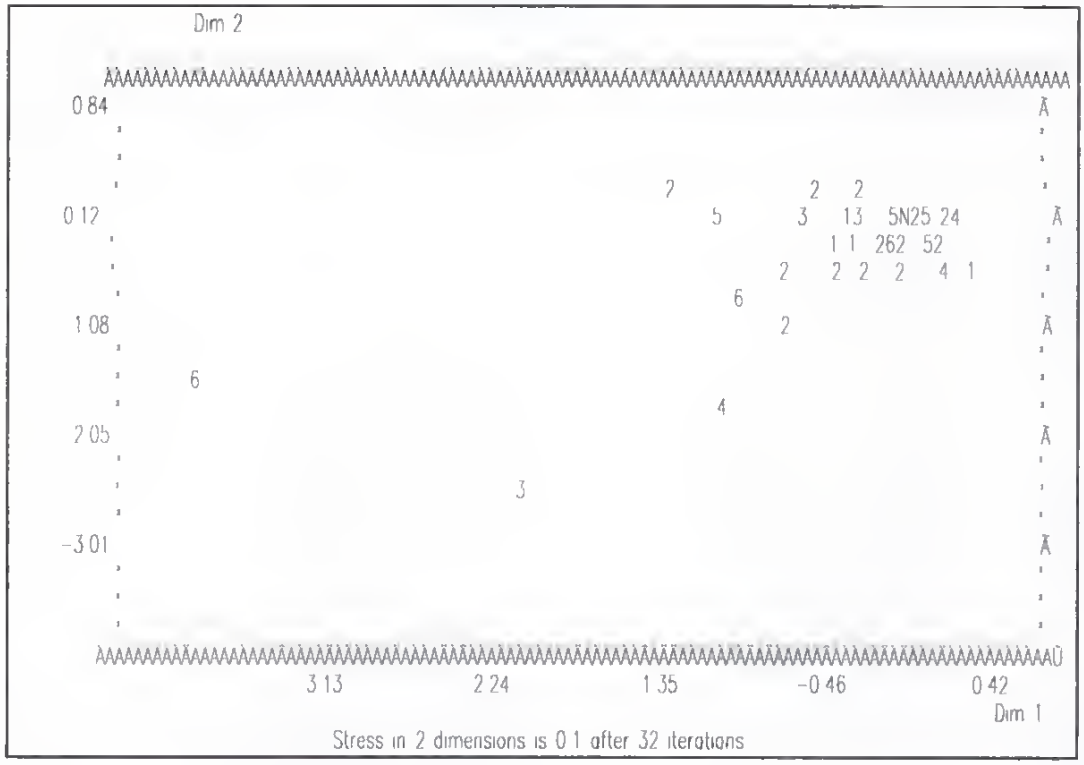


Figure 7-4. Plant identification, by ten-year age classes, using multidimensional scaling

Hierarchical scaling of plant identification response profiles is shown in Figure 7-5. In all hierarchical scaling figures single letters represent castes as follows: h (Havik Brahmin), n (Namadhari Naik), s (Sonar), b (Badagi), M (Muslim), P (Poojari Naik), k (Kodiya), p (Patgar), m (Maratha), and g (Vokkaliga Gowda); F indicates female, while M indicates male; and the numbers 1 through 6 are matched to their respective 10 year age classes.

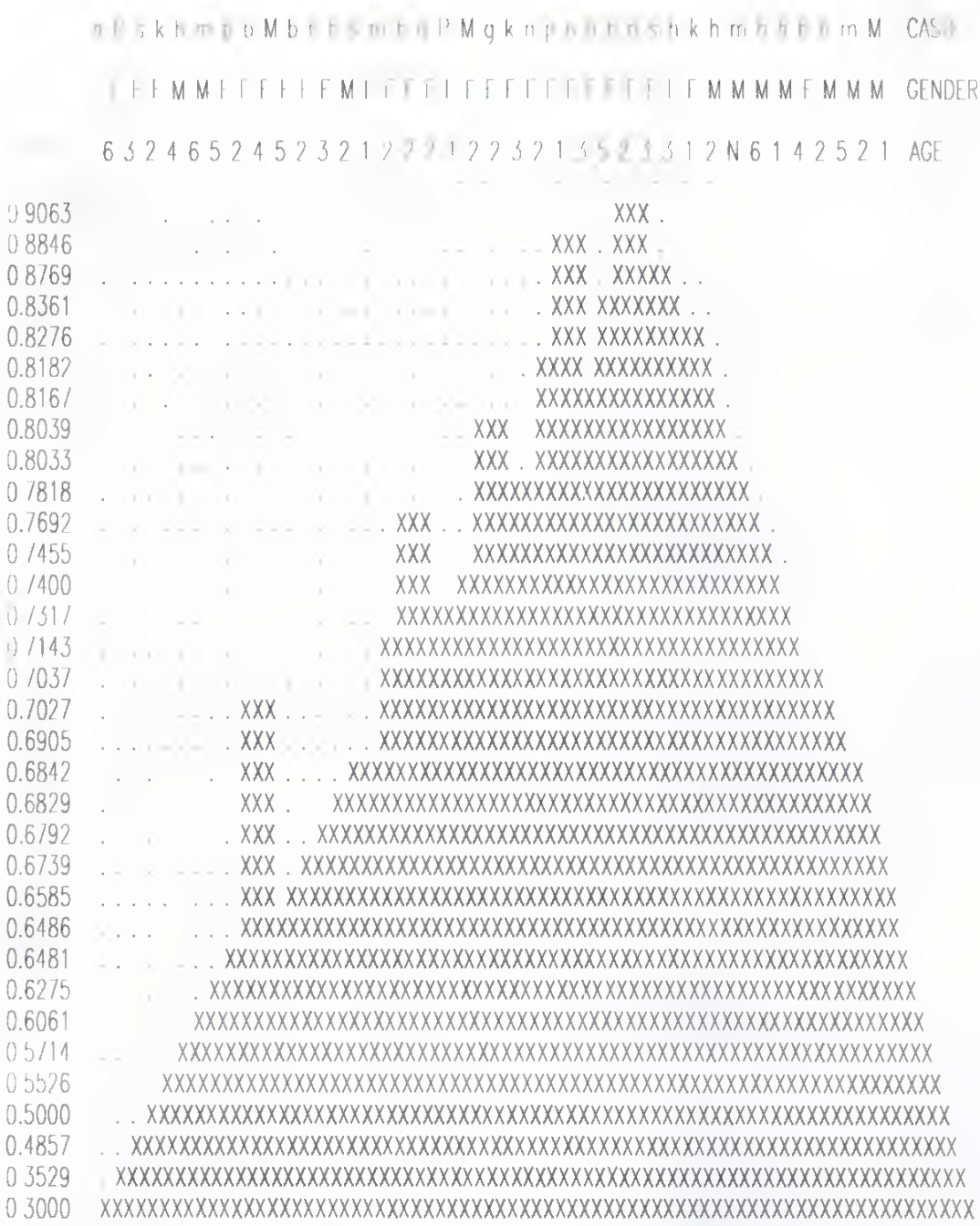


Figure 7-5. Plant identification by caste, gender, and age classes using hierarchical clustering

Four of six Havik Brahmin (h) women similarly identified 65 local plants at the 0.8167 level or greater. Four of six Havik Brahmin men similarly identified these plants at the 0.7317 level

or greater. This suggests greater internal agreement among Havik Brahmin women about plant identification than among Havik Brahmin men. There are no other notable clusters with respect to caste. Age classes are not separately clustered, and therefore do not serve to distinguish differences in plant identification among informants.

Table 7-1. Consensus analysis of informant identification of 65 plants, by caste

CONSENSUS ANALYSIS

Pseudo-Reliability = 0.936

EIGENVALUES

FACTOR	VALUE	PERCENT	CUM %	RATIO
1:	12.039	61.5	61.5	1.928
2	6.245	31.9	93.3	4.789
3:	1.304	6.7	100.0	
	19.588	100.0		

Your data are not well-explained by a single factor. This condition violates the One Culture assumption of the Consensus Model.

Consensus modeling results in Table 7-1 provide evidence that the assumption of one culture is not supported with respect to plant identification by caste. *Anthroppac 4.0* computes the eigenvalues (the ratio column in consensus analysis tables) of chance-adjusted individual similarity matrices. If the ratio of the first eigenvalue to the second eigenvalue is less than 3 to 1, the case in Table 7-1, there is evidence that informants have

at least two varying perceptions of truth about the domain of interest. The assumption of one culture is also not supported when comparing plant identification knowledge for women informants only. In contrast, a ratio of 10 to 1 would provide strong support for the assumption that informants share the same comprehensive culture, i.e. informants do not originate from different subcultures (Borgatti 1992).

To seek explanations for differences in informant plant identification knowledge consensus analysis also compares informant X survey response data matrices to identify the culturally correct identification of each plant. It then refers to this culturally defined answer key in estimating each informant's knowledge coefficient for plant identification. Informant knowledge coefficient data, for which higher decimal values represent greater relative knowledge, indicate that caste, gender, and age groups all possess a range of plant identification knowledge internally (see Table 7-2). Similarly, correlation analysis of these knowledge coefficients with respect to caste, gender, and age produced no significant results.

Several castes contain skilled field botanists. For example, three high-scoring male informants (# 28, # 33, and # 35) were all found to be ayurvedic herbalists. Comparison of Table 7-2 and Figure 7-5 does suggest that Kodiya, Vokkaliga Gowda, and most Havik Brahmin women informants are both similar and competent in plant identification. The two Kodiya women similarly identified the plants at the 0.7818 level, and had knowledge coefficients of 0.69 or higher. The two Vokkaliga

Gowda women similarly identified the plants at the 0.7143 level, and had knowledge coefficients of 0.64 or higher.

To summarize, plant identification knowledge is not uniform among informants, but cannot be easily distinguished according to caste, gender, or age. Most caste, gender, and age groups display broad intra-group differences in both plant identification profiles and plant knowledge. For Havik Brahmins agreement among women is greater than among men. With the exception of two competent herbalists, Havik Brahmin men possess lower plant identification knowledge coefficients than do Havik Brahmin women.

Table 7-2. Knowledge coefficient of informants in identifying 65 local plants with respect to caste, gender, and age class

Informant #	Caste	Gender	Age	Knowledge Coefficient
1	Ba	F	2	0.51
2	Ba	F	3	0.53
3	Ba	F	4	0.43
4	Go	F	2	0.64
5	Go	F	2	0.69
6	HB	F	1	0.57
7	HB	F	2	0.57
8	HB	F	2	0.76
9	HB	F	2	0.59
10	HB	F	3	0.72
11	HB	F	5	0.63
12	Ko	F	2	0.76
13	Ko	F	3	0.69
14	Ma	F	2	0.60
15	Ma	F	5	0.35
16	Mu	F	2	0.47
17	Mu	F	5	0.58
18	NN	F	2	0.70
19	NN	F	3	0.64
20	NN	F	6	0.22
21	Pa	F	1	0.64
22	Pa	F	2	0.37
23	Po	F	1	0.49
24	Po	F	3	0.09
25	So	F	1	0.59
26	So	F	3	0.72
27	So	F	2	0.22
28	HB	M	1	0.66
29	HB	M	2	0.51
30	HB	M	4	0.44
31	HB	M	5	0.54
32	HB	M	6	0.34
33	HB	M	NA	0.74
34	Ko	M	4	0.09
35	Ma	M	6	0.77
36	Mo	M	2	0.61
37	Mu	M	1	0.59

Average: 0.526
Std. Dev.: 0.221

Priority Use of Plants

Multidimensional scaling, hierarchical clustering, and consensus analysis are next used to compare informant response

profiles for the priority use of recognized plants, based on caste, gender, and age class.

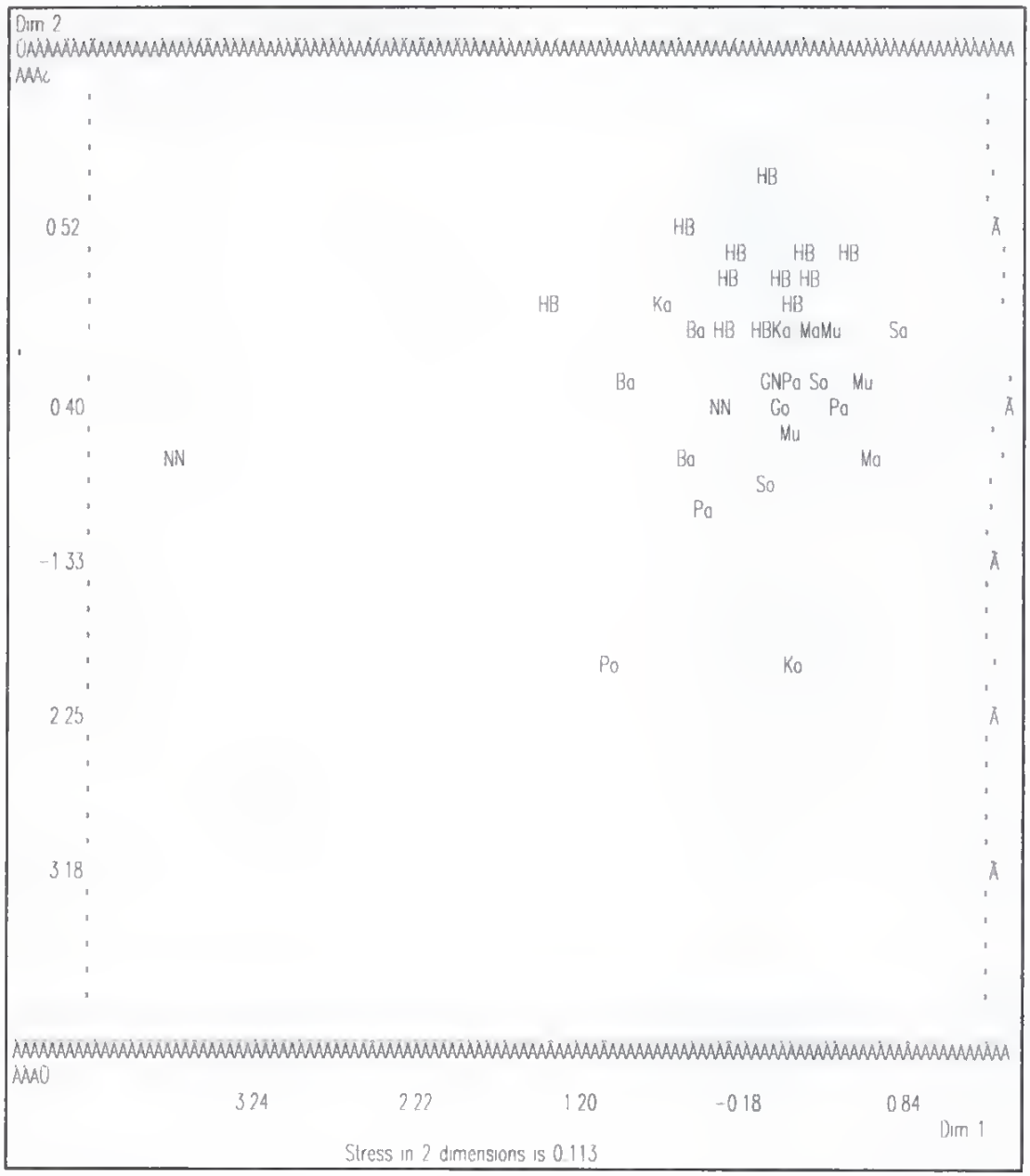


Figure 7-6. Priority use of recognized plants, by caste, using multidimensional scaling

Figure 7-6 indicates greater similarity among Havik Brahmin (HB) plant use response profiles than when compared with other caste groups. Figure 7-7 similarly shows a distinct contrast between male and female informants with respect to priority use of recognized plants. Males tended to report agriculturally-oriented uses of plants - fodder, mulch, and food. Females tended to report household and medicinal plant uses (see Appendix D) - medicines, tonics, cleansers, fiber, and tools - helping to account for this contrast. These contrasts are supported by correlation analysis of the priority use knowledge coefficient data shown in Table 7-3. Havik Brahmins reported different priority uses of recognized plants than did the other castes: $r = 0.5269$, $p = 0.001$, $n = 37$. Similarly, castes having lower social standing (Vokkaliga Gowda, Kodiya, Maratha, Moger, Poojari Naik, and Patgar) jointly reported different priority uses than did the higher status castes: $r = 0.3622$, $p = 0.028$, $n = 37$. Finally, women reported different priority uses of recognized plants than did men: $r = 0.4443$, $p = 0.006$, $n = 37$. Age class did not produce recognizable distinctions in priority use of plants response profiles.

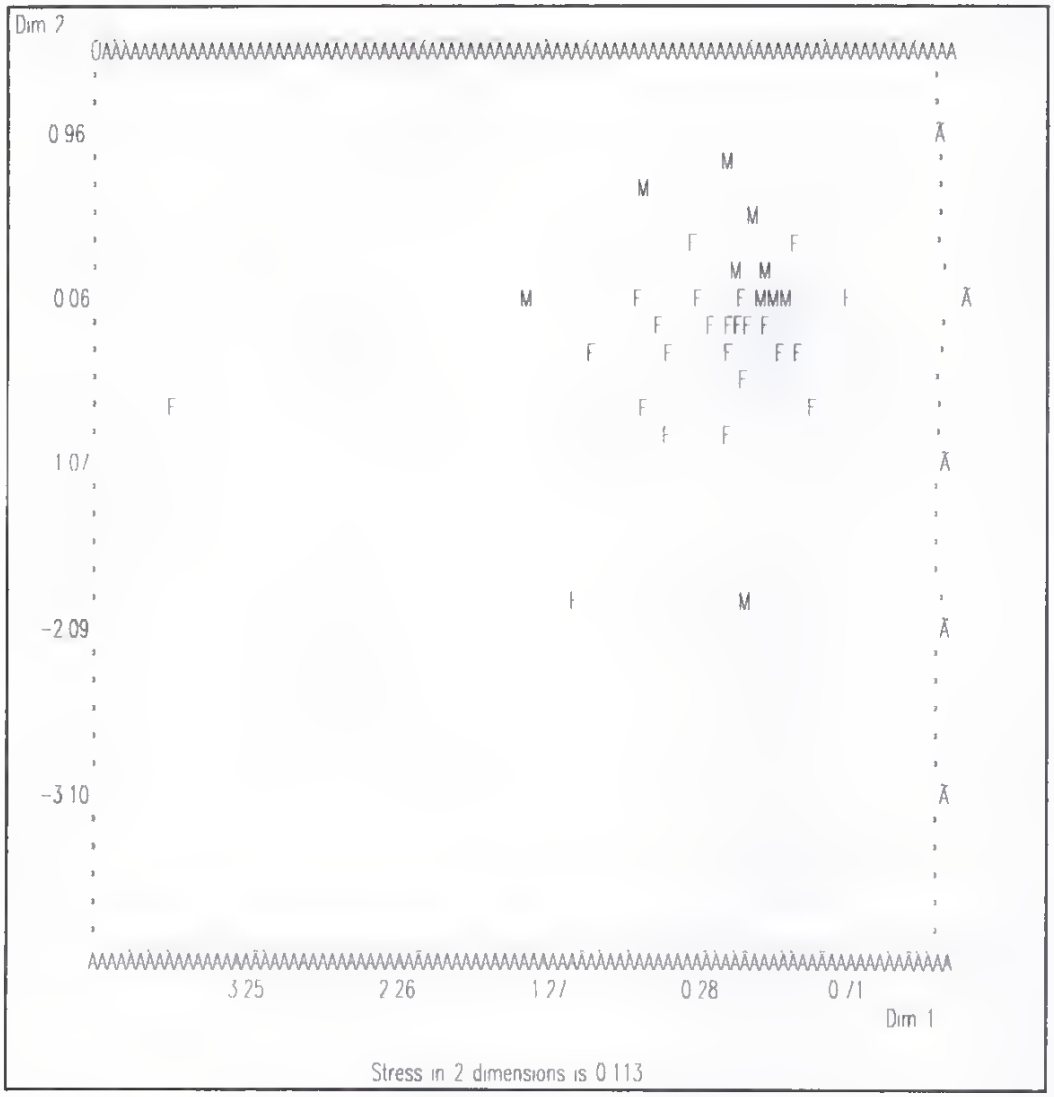


Figure 7-7. Priority use of recognized plants, by gender, using multidimensional scaling

Table 7-3. Informants' knowledge coefficients of the priority use of recognized plants, by caste and gender

Caste	Gender	Knowledge Coefficient
Ba	F	0.72
Ba	F	0.67
Ba	F	0.73
Go	F	0.84
Go	F	0.82
HB	F	0.67
HB	F	0.51
HB	F	0.69
HB	F	0.81
HB	F	0.67
HB	F	0.74
Ko	F	0.72
Ko	F	0.74
Ma	F	0.72
Ma	F	0.74
Mu	F	0.76
Mu	F	0.69
NN	F	0.78
NN	F	0.77
NN	F	0.64
Pa	F	0.71
Pa	F	0.77
Po	F	0.81
Po	F	0.70
So	F	0.65
So	F	0.77
So	F	0.73
HB	M	0.65
HB	M	0.66
HB	M	0.33
HB	M	0.53
HB	M	0.66
HB	M	0.63
Ko	M	0.67
Ma	M	0.76
Mo	M	0.69
Mu	M	0.74

Average: 0.700
Std. Dev.: 0.093

Plant Versatility (Number of plant uses)

The perceived versatility (number of uses tallied) of recognized plants is analyzed next. The heterogeneous cluster in the lower left portion of Figure 7-8 suggests differences between Havik Brahmins and all other castes in tallying the number of uses for each recognized plant species.

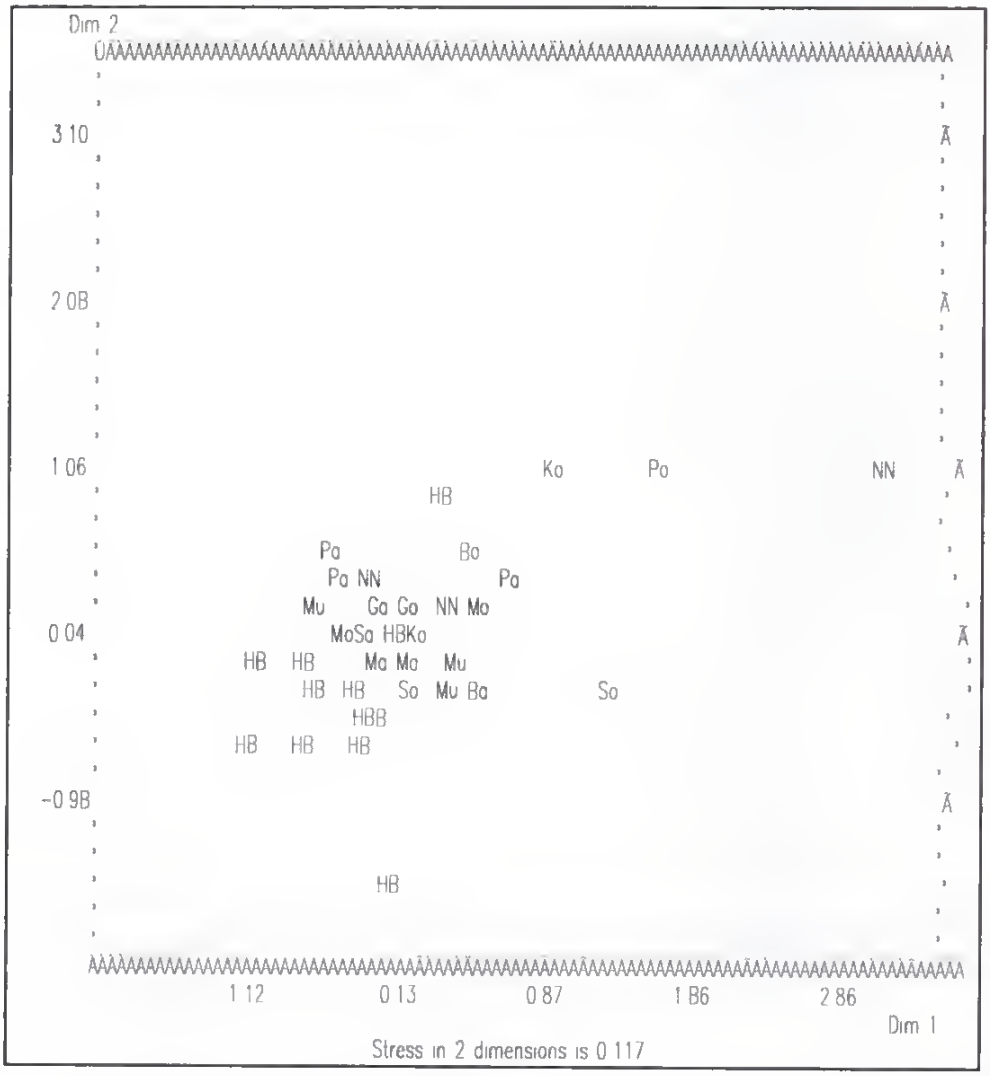


Figure 7-8. Plant versatility, or number of uses tallied for recognized plants, by caste, using multidimensional scaling

Informants positioned beyond the cluster include three of the outliers noted earlier: one Namadhari Naik (NN) - a 65 year old woman; one Poojari Naik (Po) - a 35 year old woman; one Kodiya (Ko) - a 45 year old man; plus one Havik Brahmin (HB) - a 25 year old man, and a different Sonar (So) - a 30 rather than a 27 year old woman.

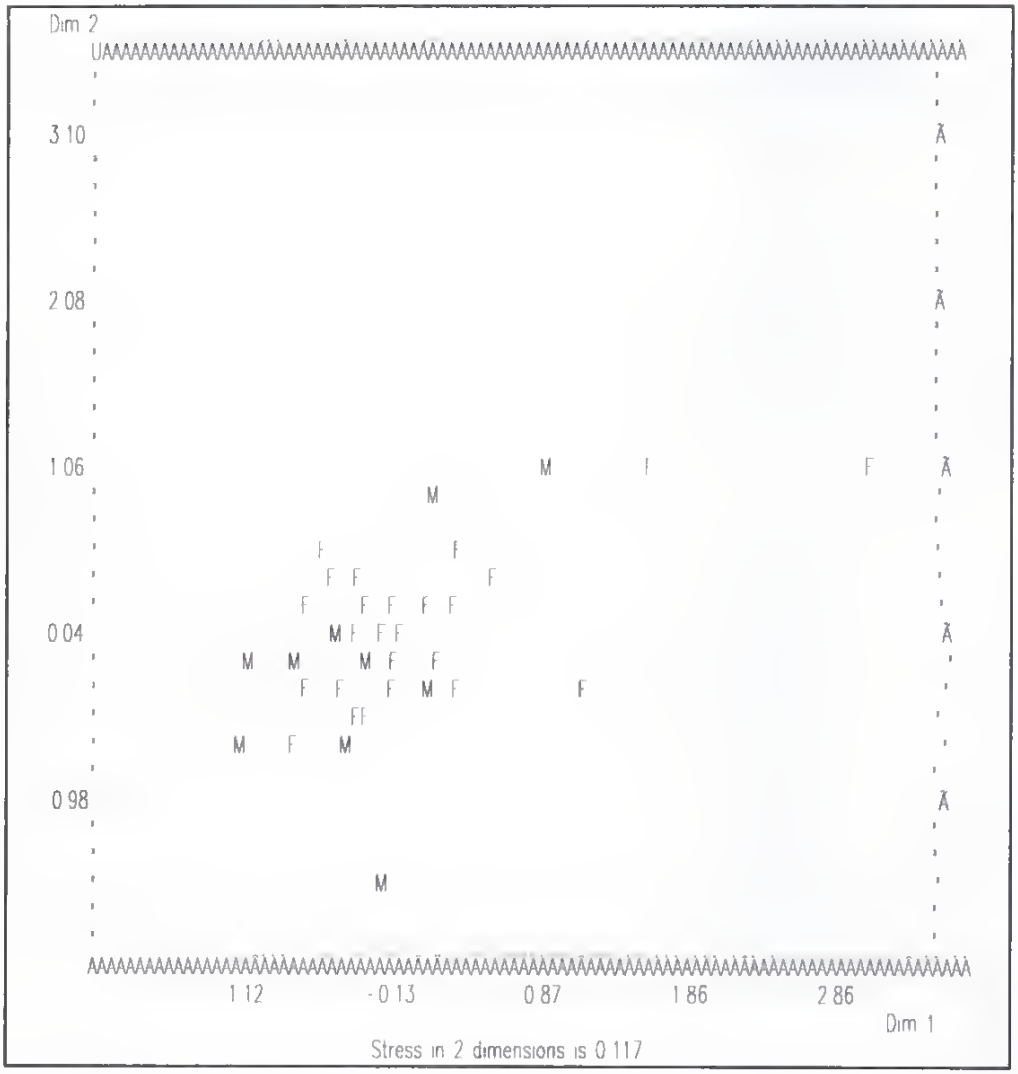


Figure 7-9. Plant versatility, or number of uses tallied for recognized plants, by gender, using multidimensional scaling

Figure 7-9 indicates that, when excluding the five outlying informants, male and female response profiles of plant versatility are located on opposite sides of the cluster.

Table 7-4. Consensus analysis of informant knowledge of plant versatility, by caste

CONSENSUS ANALYSIS

Pseudo-Reliability = 0.960

EIGENVALUES

FACTOR	VALUE	PERCENT	CUM %	RATIO
1:	15.100	80.3	80.3	5.290
2:	2.854	15.2	95.5	3.356
3:	0.851	4.5	100.0	
	18.805	100.0		

Tables 7-4 and 7-5 also suggest that informant knowledge of plant versatility is not uniform. The 1.6 ratio of eigenvalues indicates more than one cultural perception about plant versatility. This difference is accounted for on the basis of caste, and as will be shown, gender within the Havik Brahmin caste. Knowledge of plant use versatility is high among non-Havik Brahmin castes, particularly for Gowdas, Marathas, and Poojari Naiks. Females have greater knowledge coefficients than males of plant versatility - with the exception of two less knowledgeable Havik Brahmin women aged 18 and 20, and three knowledgeable males. These contrasts are supported by correlation analysis of the plant versatility knowledge coefficient data shown in Table 7-5.

Table 7-5. Informants' knowledge coefficients of versatility of recognized plants by caste, gender, and age

Caste	Gender	Age	Knowledge Coefficient
Ba	F	2	0.67
Ba	F	3	0.72
Ba	F	4	0.65
Go	F	2	0.77
Go	F	2	0.76
HB	F	1	0.40
HB	F	2	0.43
HB	F	2	0.62
HB	F	2	0.74
HB	F	3	0.58
HB	F	5	0.58
Ko	F	2	0.62
Ko	F	3	0.76
Ma	F	2	0.70
Ma	F	5	0.73
Mu	F	2	0.73
Mu	F	5	0.64
NN	F	2	0.79
NN	F	3	0.65
NN	F	6	0.57
Pa	F	1	0.63
Pa	F	2	0.77
Po	F	1	0.72
Po	F	3	0.65
So	F	1	0.65
So	F	3	0.64
So	F	2	0.67
HB	M	1	0.47
HB	M	2	0.46
HB	M	4	0.18
HB	M	5	0.35
HB	M	6	0.69
HB	M	NA	0.52
Ko	M	4	0.65
Ma	M	6	0.70
Mo	M	2	0.59
Mu	M	1	0.67

Average: 0.626
Std. Dev.: 0.129

Havik Brahmins reported fewer uses of recognized plants than did the other castes: $r = 0.7185$, $p = 0.005$, $n = 37$. Castes having lower social standing (Vokkaliga Gowda, Kodiya, Maratha, Moger,

Poojari Naik, and Patgar) jointly reported more uses of plants than did the higher status castes: r = 0.4063, p = 0.013, n = 37. Women informants reported more uses of recognized plants than did the men: r = 0.4565, p = 0.005, n = 37.

Figure 7-10 indicates that, for Havik Brahmins only, females' plant versatility response profiles are more tightly clustered, and therefore more similar than those of males.

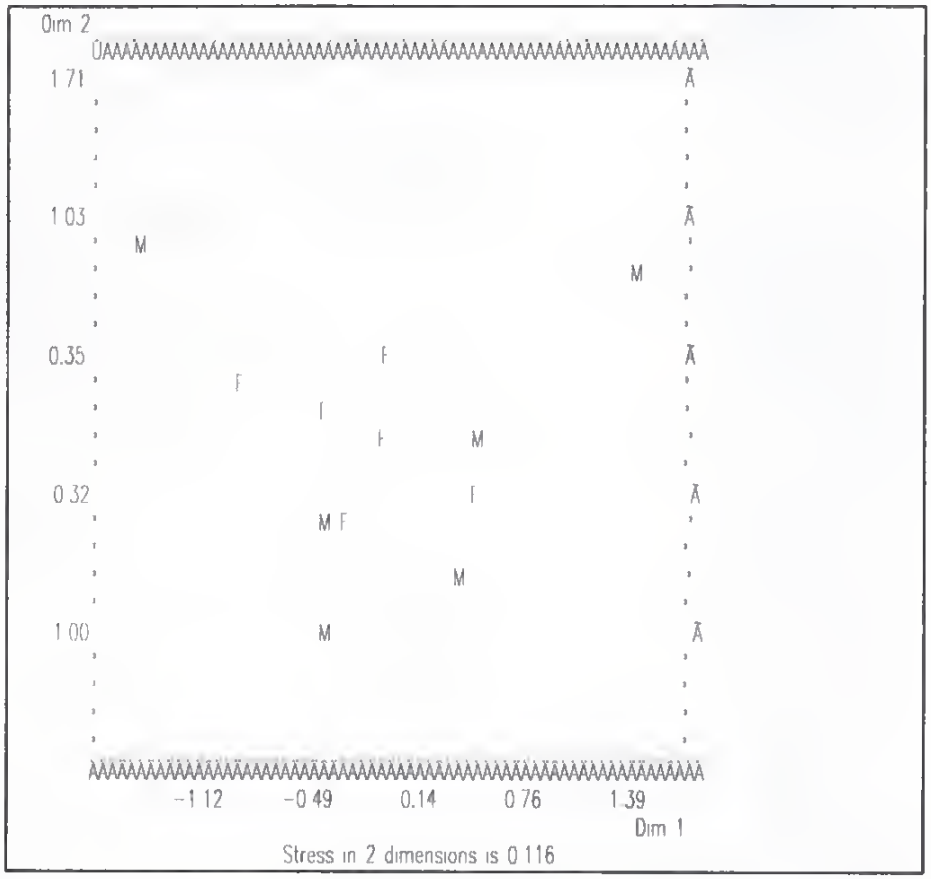
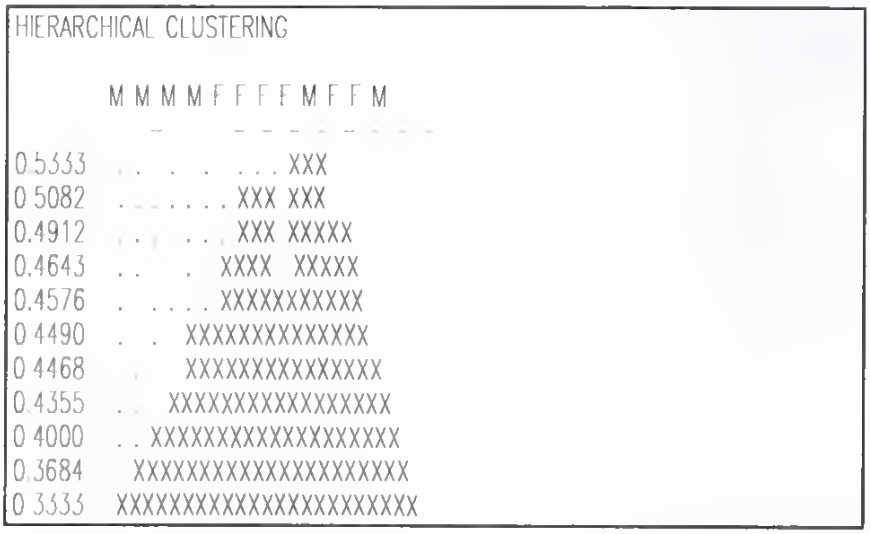


Figure 7-10. Plant versatility, or number of uses tallied for recognized plants, by gender, for Havik Brahmins, using multidimensional scaling

Hierarchical clustering analysis in Figure 7-11 further supports the notion of internal similarity among Havik Brahmin female response profiles for plant versatility (0.4576 or greater), when compared to Havik Brahmin males (0.3333 or greater). Knowledge coefficients in Table 7-6 suggest that Havik Brahmin women are more knowledgeable about plant versatility than Havik Brahmin men. Correlation analysis of the plant versatility knowledge coefficient data shown in Table 7-6 confirms that Havik Brahmin women reported more uses of recognized plants than did Havik Brahmin men: $r = 0.6627$, $p = 0.019$, $n = 12$. Age class is not reliable in distinguishing similarities in response profiles for plant versatility.


HIERARCHICAL CLUSTERING
M M M M F F F F M F F M
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0.5082 . . . . . XXX XXX
0.4912 . . . . . XXX XXXXX
0.4643 . . . XXXX XXXXX
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0.4468 . XXXXXXXXXXXXXX
0.4355 . . XXXXXXXXXXXXXXXX
0.4000 . . XXXXXXXXXXXXXXXXXX
0.3684 XXXXXXXXXXXXXXXXXXXX
0.3333 XXXXXXXXXXXXXXXXXXXXX

Figure 7-11. Number of uses tallied for recognized plants, by gender, for Havik Brahmins, using hierarchical clustering

Table 7-6. Knowledge coefficients of versatility of recognized plants, by gender, for Havik Brahmins

Gender	Age Class	Knowledge Coefficient
F	1	0.54
F	2	0.54
F	2	0.70
F	2	0.69
F	3	0.69
F	5	0.63
M	1	0.58
M	2	0.40
M	4	0.35
M	5	0.41
M	6	0.48
M	NA	0.64

Average: 0.556
Std. Dev.: 0.116

Plant Usefulness

Multidimensional scaling, hierarchical clustering, and consensus analysis are next used to compare informant response profiles about the perceived usefulness of recognized plants, based on caste, gender, and age class. The cluster of Havik Brahmins in the lower left corner of Figure 7-12 suggests differences between them and other castes with respect to plant usefulness response profiles, though the stress value (0.215) in two dimensions is too great to warrant confidence. Multidimensional scaling of plant usefulness in three dimensions amplifies these differences, while only moderately reducing stress (0.171). Analogous differences between males and females are obtained when comparing perceived plant usefulness profiles by gender (see Figure 7-13), though stress values remain the same. Age class did not produce recognizable distinctions in

perceived plant usefulness response profiles. Multidimensional scaling results of plant usefulness response data are, by themselves, inconclusive.

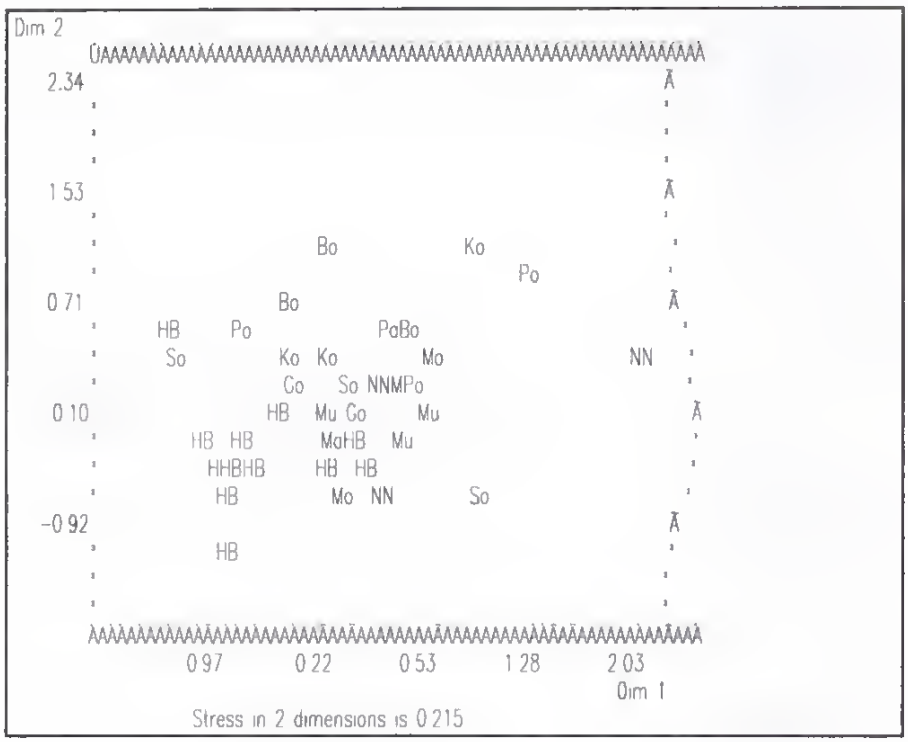

Figure 7-12. Perceived usefulness of recognized plants, by caste, using multidimensional scaling

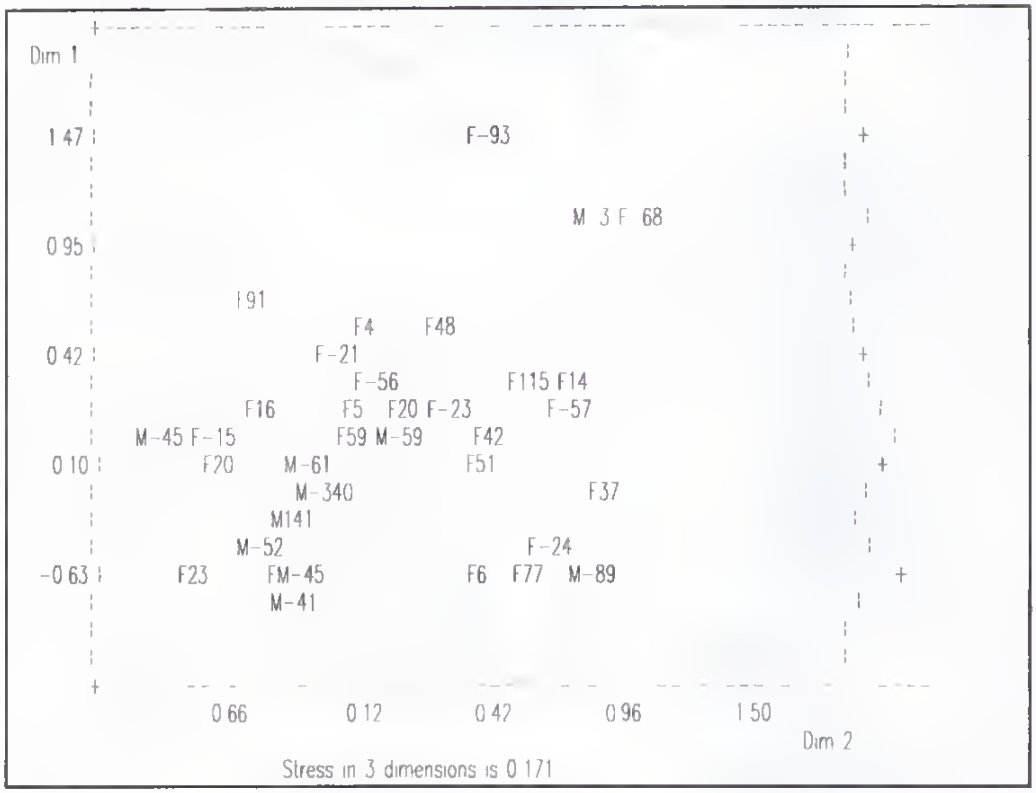

Figure 7-13. Perceived usefulness of recognized plants, by gender, using multidimensional scaling

Hierarchical clustering analysis also fails to produce clear distinctions in plant usefulness profiles with respect to either caste, gender, or age class.

Consensus modeling results in Table 7-7 provide evidence that the assumption of one culture regarding perceived usefulness of recognized plants is not supported, with respect to caste. However, Table 7-8 suggests that differences in perceived plant usefulness are better explained on the basis of gender, rather than caste. With the exception of two less knowledgeable Havik Brahmin women and one knowledgeable Maratha man, females have

higher knowledge coefficients of the perceived usefulness of recognized plants than males. This conclusion is supported by correlation analysis of perceived plant usefulness knowledge coefficient data shown in Table 7-8. Women perceived the usefulness of recognized plants differently than did the men: $r = 0.3505$, $p = 0.033$, $n = 37$. Age class is not reliable in distinguishing similarities in response profiles for plant usefulness.

Table 7-7. Consensus analysis of perceived usefulness of recognized plants, by caste

CONSENSUS ANALYSIS

Respondent Reliability = 0.946

EIGENVALUES

FACTOR	VALUE	PERCENT	CUM %	RATIO
1:	12.512	76.4	76.4	5.378
2:	2.327	14.2	90.6	1.511
3:	1.539	9.4	100.0	
	16.378	100.0		

Table 7-8. Knowledge coefficients of perceived usefulness of recognized plants, by caste and gender

Caste	Gender	Knowledge Coefficient
Ba	F	0.62
Ba	F	0.59
Ba	F	0.39
Go	F	0.65
Go	F	0.77
HB	F	0.48
HB	F	0.38
HB	F	0.61
HB	F	0.72
HB	F	0.60
HB	F	0.71
Ko	F	0.72
Ko	F	0.71
Ma	F	0.55
Ma	F	0.48
Mu	F	0.59
Mu	F	0.58
NN	F	0.78
NN	F	0.64
NN	F	0.40
Pa	F	0.58
Pa	F	0.65
Po	F	0.59
Po	F	0.36
So	F	0.52
So	F	0.64
So	F	0.75
HB	M	0.45
HB	M	0.43
HB	M	0.32
HB	M	0.42
HB	M	0.52
HB	M	0.58
Ko	M	0.43
Ma	M	0.72
Mo	M	0.52
Mu	M	0.59

Average: 0.568
Std. Dev.: 0.123

Recognized plants receiving the highest informant usefulness scores, and their consequent rankings, are presented in Table 7-9.

Table 7-9. Rankings and usefulness scores (lower score indicates greater usefulness) of the most useful survey plants, according to survey informants

Plant name	Ranking	Score
Bambusa arundinaceae (Retz.) Willd.	1	186
Emblica officianalis Gaertner	2	203
Garcinia indica (Thouars) Choisy	3	253
Syzygium cumini (L.) Skeels	4	265
Artocarpus integrifolius L. f.	5	270
Pheonix silvestris (L.) Roxb. (Phoenix acaulis)	6	272
Dillenia pentagyna	7	288
Caryota urens L.	8	301
Careya arborea Roxb.	9	314
Mytrigyne parviflora	10	325
Holarrhena antidysenterica (Roxb. ex Fleming)	11	334
Cinnamomum zeylanicum Blume	12	348
Terminalia cebula (Gaertner) Retz.	13	366
Hemidesmus indicus (L.) Schult.	14	367
Calycopteris floribunda Roxb.	14	367
Sapindus emarginata L.	15	368
Aporosa lindleyanna	16	371
Anacardium occidentale L.	17	373
Anamirta paniculata Colebr.	18	377
Artocarpus lacucha	19	382
Duranta plumeria	20	383
Albizia Amara Biovin.	21	384
Semecarpus anacardium L. f.	22	391
Randia dumetorum Lamk.	23	392
Aerua lanata Juss.	24	393
Carissa carandas L.	24	393
Buchanania latifolia Roxb.	24	393

Only 4 of these 27 most useful plant species are reported to be locally abundant: *Holarrhena antidysenterica*, *Calycopteris*

floribunda, *Dillenia pentagyna*, and *Hemidesmus indicus*. The other 23 species are in demand locally, and might induce a favorable response if included in future social forestry programs.

Plant Abundance

Plant species most often reported to be locally abundant include: *Coloccasia esculenta*, *Coloccasia esculenta* var. black, *Holarrhena antidysenterica*, *Cassia fistula*, *Calycopteris floribunda*, *Dillenia pentagyna*, *Michelia chempaca*, *Vitex negundo*, *Hemidesmus indicus*, and *Holigarna aronottiana*. Consensus analysis results alone indicate slight contrasts in informant response profiles about perceived local abundance of recognized plants, and then only on the basis of age class. This conclusion is supported by correlation analysis of perceived plant abundance knowledge coefficient data shown in Table 7-10. Younger informants displayed relative greater knowledge about local abundance of recognized plants than did older informants: $r = 0.3551$, $p = 0.034$, $n = 36$. However, 20 of 37 informants were less than 30 years old at the time of the survey, and this may have weighted collective knowledge about plant abundance in the direction of these younger informants.

Table 7-10. Knowledge coefficients of perceived local abundance of recognized plant species by caste, gender, and age

Caste	Gender	Age Class	Knowledge Coefficient
Ba	F	2	0.60
Ba	F	3	0.56
Ba	F	4	0.38
Go	F	2	0.67
Go	F	2	0.76
HB	F	1	0.47
HB	F	2	0.42
HB	F	2	0.68
HB	F	2	0.71
HB	F	3	0.63
HB	F	5	0.62
Ko	F	2	0.71
Ko	F	3	0.70
Ma	F	2	0.56
Ma	F	5	0.54
Mu	F	2	0.62
Mu	F	5	0.61
NN	F	2	0.73
NN	F	3	0.60
NN	F	6	0.34
Pa	F	1	0.67
Pa	F	2	0.66
Po	F	1	0.64
Po	F	3	0.46
So	F	1	0.54
So	F	3	0.52
So	F	2	0.73
HB	M	1	0.60
HB	M	2	0.44
HB	M	4	0.34
HB	M	5	0.49
HB	M	6	0.54
HB	M	NA	0.62
Ko	M	4	0.38
Ma	M	6	0.68
Mo	M	2	0.57
Mu	M	1	0.64

Average: 0.5792
Std. Dev.: 0.113

Discussion of Survey Results

Proper identification of 65 species of local plants was not uniform among informants, but could not be easily distinguished by caste, gender, or age. Survey informants from each of these three groups expressed a range of plant identification knowledge. Contrary to expectation, informants from lower status castes did not identify plants any better than informants from higher status castes. Havik Brahmin women expressed greater internal agreement about the identity of local plants than did Havik Brahmin men. They also had higher plant identification knowledge coefficients than did the men.

Havik Brahmins did have different plant use priorities than other caste groups. Similarly, the six lower status castes had different plant use priorities than the six higher status castes. Men of all castes had different plant use priorities than did women. Men emphasized fodder and mulch uses of plants, while women gave more importance to plant-derived medicines, tonics, fiber, tools, and food uses of plants.

Women of all castes both agreed and knew more about the multiple uses of plants than did men. Women of all castes also had different perceptions of the usefulness of recognized plants than did men - particularly Havik Brahmin men. Women were more sensitive to how plant resources can be used, because they are the primary processors of plant materials into consumable household products.

Knowledge of the multiple uses of recognized plants did increase as a function of increasing caste dependence upon these

products for subsistence. The Havik Brahmin men interviewed knew less about the multiple uses of recognized plants than other informants. Informants from the six lower status castes knew more about the multiple uses of recognized plants than informants from the six higher status castes. That informants from higher status castes own more spice gardens and/or livestock helps explain why their perceptions about plant uses is more limited and specific.

Informants less than 30 years of age agreed among themselves and were more knowledgeable about the local abundance of recognized plants than were older informants. The fact that 55 percent of informants were less than 30 years old may have weighted collective knowledge about plant abundance in the direction of these informants. In all other measures of plant knowledge and use, age class affiliation did not distinguish differences among informants. Terkanahalli villagers apparently learn about the distribution of local forest plants from an early age.

None of the 122 informants felt that multiple species plantations (MSPs) are an improvement over the minor forests they replace. Young MSPs support less plant diversity than minor forests, and their creation further diminishes the number of remaining minor forests tracts. Broad-based dependence on minor forest products for wood fuel, fiber, and fruits clarifies why all informants favored minor forests over MSPs.

All caste groups felt that MSPs threatened their most important collection activity in minor forests, wood fuel

gathering. All informants placed the greatest emphasis on minor forests as sources of wood fuel, except female Muslim informants, who buy wood fuel from the local forest department depot. Informants also wished to retain access to minor forests' fuel wood resources in the future.

Spice garden owners, originating exclusively from the four most affluent castes, esteemed minor forests primarily as mulch repositories. Only Havik Brahmins and one Namadhari Naik that have access to *betta* forests for mulch collection do not rely on minor forests for mulch. Brahminical informants of modest means like Sonar and Lingayat, however, reported collecting a variety of fruits, fiber, and fungi from minor forests.

CHAPTER 8
TOWARDS PARTICIPATORY MANAGEMENT OF FOREST RESOURCES

Introduction

The forest resource use surveys just described can be used as a base from which to devise participatory, community-based reforestation programs. The Terkanahalli study shows that knowledge about and use of forest resources varies among forest-dependent people. These differences are sometimes a reflection of gender or caste status - and the concomitant forest access/use privileges associated with particular castes. Intra-community differences in access to, knowledge, and use of forest resources highlight the practical difficulties in initiating appropriate, broad-based community forestry programs. Conversely, such differences help identify distinct social groups or networks that can serve as a functional base in participatory reforestation initiatives. This chapter presents an approach that applies local knowledge and a spatial information perspective to the resolution of conflicts over natural resources.

Participatory Research in Forest Planning and Management

The survey results presented in Chapters 6 and 7 suggest that the most immediate and comprehensive information resource about a specific culture is a sample of informants randomly selected from that culture. Few scientific research programs

depend on the research subjects themselves to define the direction and scope of a proposed study. The presumption of social science scholars to know more about a culture than members of that culture has been a recurrent cause for the failure of socio-economic development programs.

In Terkanahalli Village an informant-driven research program could, for example, direct research to improved management of plant species perceived to be versatile in their use and/or locally rare. Valuable and rare plant species are precisely those that informants prioritize for use in local environmental rehabilitation programs. Forestry extension programs should therefore emphasize planting of rare, multiple-use species that are popular locally (Agarwala 1985), and that are not reserved or restricted in their utilization. This is a strong base from which to initiate popular participatory reforestation schemes. It also provides a real incentive for local communities to cooperate in the protection of replanted forests.

There is a risk that different sub-cultures within a culture may assign conflicting priorities and values to natural resources. In such discordant resource use priorities lies the root of the struggle over resources - and their consequent degradation. The example of minor forest resources in peninsular India makes this point well. Two-thirds of all minor forests in the Sirsi Forest Division are degraded and have low productivity. Yet because of their juxtaposition to both neighboring hamlets and reserved forests, these forests are valued differently by those who have an interest in using them. Some minor forests are

important to foresters as protective buffers against further encroachment into valuable reserved forests, as corridors to protect riparian wetlands, or may themselves possess valuable timber. In contrast, local people, especially the landless, often depend on nearby minor forest resources for subsistence purposes. At the sub-village or hamlet level, minor forest use priorities may vary according to caste affiliation and gender. If these contrasting priorities are not properly understood and accounted for, there is always the chance that disenchanted subcultures will sabotage local reforestation efforts.

Identifying attitudinal differences between subcultures is the primary function of analytical tools like those used in the forest resource use surveys. After differences in resource use priorities between subcultures become clear, the next logical step is to initiate negotiation among subcultures - to reach compromise resource management agreements. For example, when one subculture (e.g. state foresters) yields to the use wishes of another (e.g. wood fuel gatherers) in some forest tracts, the former could expect to have its silvicultural priorities acknowledged in other tracts. Responsibility for the welfare and maintenance of specific forest tracts could increase in measure with the use rights conferred. To achieve this goal of responsible resource management requires that conflicts between subcultures competing for limited resources be identified and understood. Participatory, survey-based analytical procedures can produce subcultural information quickly and accurately.

Using Spatial Information to Catalyze Local Participation

In India, conversion of forest lands or changes in their ownership are prohibited by the Indian constitution - except for occasional regularization of forest encroachment mentioned earlier. Therefore, if changes in access to forests are to occur, attention must focus on limited transfers of forest resource tenure to local people. To do this properly requires detailed knowledge of where specific resources are, who is using them, and the intensity of use pressure on them. Minor forests represent the arena of greatest potential for allocation and local sharing of resource tenure, since this is where overlap in use agendas is most pronounced - both between foresters and villagers, and between villagers themselves. Minor forests also have the greatest potential to increase yields of forest products since their yield potential is the most underutilized of all forest types in Karnataka.

At the hamlet level, forest use priorities of different caste, gender, or other socio-economic groups can be gathered and presented spatially at little expense. A facilitator-guided workshop involving every family in open discussion and planning about the future development and use of local forest resources would be an efficient means to collect, present, and analyze such information. Use of Geographic Information System (GIS) techniques, whether via hand-drawn acetate maps, digital data bases, or both would be the heart of the forest management workshop process. Such spatial data could be case specific and easily updated, to keep improving its accuracy and utility. Most

importantly, maps generated by this exercise would be attractive to view, engaging the interest and participation of resource users.

Local management of spatial resource information using GIS technology is now globally feasible both technically and economically. GIS software packages have become portable, and are possible to operate in even remote rural settings. Presentation of natural resource information from a landscape perspective can focus and guide informed dialog in the resource management decision-making process. By contributing their perceptions and knowledge to a spatial inventory of resources, even the most socially disadvantaged villagers become active players in resource management decisions affecting their community. Such GIS-based development efforts have been observed by the author in Borneo, where participatory forestry projects are catalyzed through village mapping activities. Spatial information gathering, village mapping, and local manipulation of spatial data strengthen communities in their efforts to autonomously manage local resources.

Community-Based Natural Resource Management: An Applied Scenario

IDRISI is a low-cost, widely used GIS that is appropriate for use in spatial data collection, analysis, and presentation in rural areas of lesser industrialized countries (Eastman 1990). In community-based workshop exercises, local resource maps generated from IDRISI could be used as centerpieces for joint natural resource management planning among all workshop

participants. All actors who have an impact on local resources, including local people and government department staff, would become contributors to the creation of map overlays of spatial information about a community's resources. This information would then be superimposed on a map of the village area in different combinations - depending on the resource allocation/use question under discussion. Areal overlap of information would represent tracts having multiple use attributes as defined by workshop participants. Negotiation and compromise concerning future management and use of these sites would be necessary to ensure that all participants achieve their resource use objectives. Whenever participants yield to the use wishes of others in some tracts, they could expect to have their own use wishes acknowledged in others. Enhanced control and tenure over natural resources could be accorded to those who obtain workshop recognition as favored users of specific tracts, however responsibility for the welfare and maintenance of those tracts would increase in equal measure. The workshop process would revolve around consensus of who should enjoy the use of which resources, and under what conditions of responsibility.

Community resource tenure arrangements constantly change, whether due to birth, death, weather, politics, or local economic conditions. An IDRISI spatial accounting system of local resource conditions and use arrangements could be routinely updated to serve as a reference in ongoing resource negotiations.

With respect to site selection for multiple species plantations described in this study, workshop participants could

create their candidate site overlays in participant interest groups, and then present their selections to the entire workshop in spatial form. This would spur debate over a silvicultural prescription for local forests in space and in time. Whether resulting management decisions would be "good" or "bad" depend entirely upon the aims and perspectives of those who manage or in some way depend on forest resources (Vale 1982). If the wishes of all workshop participants are adequately addressed, then joint decisions could be described as good decisions.

APPENDIX A
BASELINE SURVEY OF 122 HOUSEHOLDS, TEREKANAHALLI VILLAGE,
NORTH KANARA DISTRICT, KARNATAKA, INDIA

1) DATE

2) LOCATION: Hamlet within village

3) NAME

4) GENDER

5) AGE

6) CASTE

7) OCCUPATION

8) MARITAL STATUS

9) HOUSEHOLD INFORMATION: age group, gender, and literacy

	# MALES	# FEMALES
less than 18 years old		
18-60 years old		
more than 60 years old		
literacy by gender		

10) HOUSE TYPE

11) ROOF TYPE

12) ANNUAL FAMILY INCOME (Indian Rs.)

less than Rs. 2000 (US$ 75)

Rs. 2000-5000

Rs. 5000-10,000

Rs. 10,000-20,000

more than Rs. 20,000

Appendix A--continued

13) LIVESTOCK OWNERSHIP (type and quantity)

14) LANDOWNERSHIP (type, quantity, and ownership status)

15) HOUSE LOCATION

16) FOREST PRODUCTS PERSONALLY COLLECTED BY RESPONDENT (type, quantity, month of collection, type of forest where collected)

17) FOREST PRODUCT USE (subsistence or commercial use)

18) FOREST PRODUCTS TRADITIONALLY COLLECTED BY LOCAL PEOPLE (respondent's opinion)

19) IF SUCH PRODUCTS ARE LOCALLY SCARCE, WHY HAS SUCH SCARCITY OCCURRED (respondent's opinion)?

20) WHAT BENEFIT(S) DO YOU AND YOUR FAMILY ENJOY FROM RECENTLY PLANTED MULTIPLE SPECIES PLANTATIONS (MSPs)?

21) WHAT DISBENEFITS DO YOU AND YOUR FAMILY EXPERIENCE FROM RECENTLY PLANTED MSPs?

22) ARE MSPs AN IMPROVEMENT OVER THE MINOR FORESTS THAT THEY REPLACE? WHY OR WHY NOT?

23) IS THERE AN INCRESING NEED FOR FORESTS IN AND AROUND YOUR VILLAGE? IF SO, WHY?

24) WHAT TREE SPECIES WOULD YOU LIKE TO HAVE PLANTED IN THE NEW FORESTS/MSPs?

25) WHAT IS YOUR OPINION OF THE BEST METHOD FOR CREATING THE KIND OF NEW FORESTS YOU DESIRE? (location and method)

APPENDIX B
PLANT SPECIES INCLUDED IN A MINOR FOREST VEGETATION USE SURVEY, NORTH KANARA DISTRICT, KARNATAKA, INDIA

SCIENTIFIC NAME	FAMILY	KANNADA NAME
Hemidesmus indicus (L.) Schult.	Periplocaceae	haaluballi
Anamirta paniculata Colebr.	Menispermaceae	aadaemunni
Rhynchostylis sp.	Orchidaceae	sitaydundae
Borreria hispida	Rubiaceae	jerrlae soppu
Cassia sophera L.	Faboideae	yelavarigae kudi
Coloccasia esculenta (L.) Schott	Araceae	kaesa
Coloccasia esculenta var. black	Araceae	karey kaesa
Amaryllis zeylanicum L.	Amaryllidaceae	isamungeri
Coleus malabaricus Benth.	Lamiaceae	sambaara soppu
Polygonum aviculare L.	Polygonaceae	kannaekudi
Elephantopus scaber L.	Asteraceae	naelagonagalu
Tylophora aposinata W. & A.	Asclepiadaceae	punyalla
Hibiscus rosa sinensis L.	Malvaceae	bili daasavaala
Graptophyllum pictum (L.) Griff.	Rubiaceae	daasaputrae
Bulbophyllum sp.	Orchidaceae	imarabaalaekaayi
Gardenia gummifera L. *f.*	Rubiaceae	bikkae
Ixora grandiflora	Rubiaceae	biliholaeaasawaala
Ixora grandiflora var. dark	Rubiaceae	kempu holaedaasawaala
Aerua lanata Juss.	Amarantaceae	howlapatli
Vitex negundo L.	Verbenaceae	lakki
Duranta plumeria	Verbenaceae	paytae mullu
Calotropis gigantea (L.) Dryander ex Aiton f.	Asclepiadaceae	ekkae
Lawsonia alba L. var.*rubra*	Lythraceae	mudurunggi/henna
Randia dumetorum Lamk.	Rubiaceae	kaarae
Pandanus odoratissimus Roxb.	Pandanaceae	kyadigae
Pandanus fascicularis	Pandanaceae	mundigae
Adhatoda vasica Nees	Acanthaceae	baesaala
Spondias mangifera L.	Anacardiaceae	amataekaai
Fluggea virosa Willd.	Euphorbiaceae	sanaelay
Carissa carandas L.	Apocynaceae	kavali
Calycopteris floribunda Roxb.	Combretaceae	kamusalu
Holarrhena antidysenterica (Roxb. ex Fleming) Wallich ex A. Dc.	Apocynaceae	kodasa

Appendix B--continued

SCIENTIFIC NAME	FAMILY	KANNADA NAME
Bambusa arundinaceae (Retz.) Willd.	Poaceae	beederu/bamboo
Anacardium occidentale L.	Anacardiaceae	gaeru
Pheonix silvestris (L.) Roxb. *(Phoenix acaulis)*	Arecaceae	ichala
Caryota urens L.	Arecaceae	byney mara
Emblica officianalis Gaertner	Euphorbiaceae	naelli
Diospyros melanoxylon Roxb.	Ebenaceae	tumbari
Ficus aspermagara L.	Moraceae	gutthi/garagutthi
Gmelina arborea L.	Verbenaceae	shivani
Semecarpus anacardium L. f.	Anacardiaceae	guddaegaeru
Annona squamosa L.	Annonaceae	ramphal
Holigarna aronottiana Hook. F.	Anacardiaceae	holagaere
Anthocephalus cadamba Miq.	Rubiaceae	apatia
Saraca indica L.	Caesalpinoideae	ashok
Aporosa lindleyanna	Euphorbiaceae	sallae
Syzygium cumini (L.) Skeels *(Eugenia jambolanum* Lam.)	Myrtaceae	kannaeralu
Terminalia cebula (Gaertner) Retz.	Combretaceae	analae kaayi/hirda
Cinnamomum zeylanicum Blume	Lauraceae	dalchini
Sapindus emarginata L.	Sapindaceae	antualah
Careya arborea Roxb.	Lethycidaceae	kavalu/kavuli
Artocarpus lacucha	Moraceae	atlakae
Strychnos nux-vomica L.	Loganiaceae	kaasarakaa
Mytrigyne parviflora	Rubiaceae	kalum
Buchanania latifolia Roxb.	Anacardiaceae	nurukalu
Garcinia indica (Thouars) Choisy	Clusiaceae	murugalu
Vateria indica L.	Dipterocarpaceae	duupa
Dillenia pentagyna	Dilleniaceae	kanagallu
Michelia chempaca L.	Magnoliaceae	sampigae
Cassia fistula L.	Caesalpinoideae	kakkaayi
Albizia Amara Biovin.	Mimosoideae	bilkumbi
Artocarpus integrifolius L. f.	Moraceae	halasu
Aegle marmelos (L.) Corr. Serr.	Rutaceae	putrae/bilvaputrae
Casuarina equisetifolia L.	Casuarinaceae	galli mara
Acacia auriculiformis Cunn. Ex Benth.	Mimosoideae	*Acacia*

Source for verification of latin binomials: USDA Agriculture Research Service Handbook 505. 1986

APPENDIX C
MINOR FOREST PRODUCT USE PREFERENCE SURVEY,
TEREKANAHALLI VILLAGE, NORTH KANARA, KARNATAKA, INDIA

NAME: MALE/FEMALE: AGE: CASTE: HAMLET:

USING 3X5 PHOTOS OF 65 LOCALLY IDENTIFIED PLANT SPECIES:

1) WHICH OF THESE PHOTOGRAPHED PLANTS CAN YOU IDENTIFY?

2) OF THE PLANTS THAT YOU IDENTIFIED, CAN YOU TELL HOW THEY ARE USED?

3) PLACE EACH SELECTED PHOTO ON ONE OF THE AREAS MARKED:

VERY USEFUL USEFUL SLIGHTLY USEFUL NOT USEFUL

HARMFUL DON'T KNOW

4) PLACE EACH SELECTED PHOTO ON ONE OF THE AREAS MARKED:

VERY COMMON COMMON RARE VERY RARE NEVER FOUND

5) RESELECT ANY OF THE SELECTED PHOTOS/PLANTS THAT YOU COLLECT IN MINOR FOREST (MF) AREAS.

6) PLEASE RANK THE SELECTED PHOTOS/PLANTS IN ORDER OF THEIR USEFULNESS TO YOU.

(The interviewer should say that "USEFULNESS" means the provision of basic personal and family needs, AND also income generation if such is the case.)

7) OF THE TEN MOST "USEFUL" PLANTS, HOW MUCH OF EACH DO YOU COLLECT EACH YEAR?

8) REPEAT QUESTIONS 5-7 FOR SOPPINA BETTA (SB) FOREST AREAS, IF APPROPRIATE.

APPENDIX D
LOCAL USES OF PLANT SPECIES, TEREKANAHALLI VILLAGE,
NORTH KANARA, KARNATAKA, INDIA

SPECIES NAME	LOCAL USE(S) and (PUBLISHED/DOCUMENTED USES)
Hemidesmus indicus (L.) Schult.	Root extract mixed with milk serves as infant growth tonic; Extract is taken during pregnancy to increase milk production. (Root extract treats loss of appetite, dyspepsia, fever, skin diseases related to syphilis, bowel disorders, leucorrhoea, soft tissue infections, and chronic cough. Root paste is applied to swellings and rheumatic joints.)
Anamirta paniculata Colebr. (*Cocculus suberosus* W. & A.)	Leaves produce an edible dry curry; Root extract paste treats children's stomach worms, serves as a blood cleansing agent, and also reduces body heat/sweats. (Leaf juice helps extract guniea worms. Dried fruit is a powerful narcotic. Berry ointment treats skin fungi/infections. Pulverized berries are used as an insecticide and fish poison. Seeds contain picrotoxin for treatment of convulsions and paralysis.)
Rhynchostylis sp.	Inflorescences serve as hair decoration and religious offerings.
Borreria hispida	Plaster for cutaneous wounds in cattle; Stems serve as cattle fodder.
Cassia sophera L.	Ingredient in curry; Stem is ground with jaggery for treatment of jaundice; Roots are eaten to improve digestion. (Entire plant decoction is expectorant for bronchitis. Leaves have purgative action. Leaves and sugar water drink treats jaundice. Bruised leaves and root bark paste treats ringworm and skin ulcers. Bark infusion acts as cathartic and is also felt to remedy diabetes.)
Coloccasia esculenta (L.) Schott	Salve treats swelling in cattle; Salve eases the extraction of thorns from skin; Starch food source.

Appendix D--continued

Coloccasia esculenta var. black	Starch food source.
Amaryllis zeylanicum L.	Leaf juice treats uncontrolled sweating/loss of body fluids. (Juice from leaf pulp functions as an emetic. Bruised hot leaves coated with mustard oil treat inflamed joints and sprains. Pulp juice also treats earache.)
Coleus malabaricus Benth.	Greens are dried on coals and then mixed with honey to treat colds/influenza, to reduce throat phlegm, soothe sore throats, and to aid digestion; Food source.
Polygonum aviculare L.	Decoction is mixed with rice and butter to improve digestion and to treat dysentery.
Elephantopus scaber L.	Clotting agent in plasters that stops cutaneous bleeding (for cattle also); Treats ear ache and fluid drainage from ear infections. (Leaves boiled in coconut oil treat skin eczema and ulcers. Shoot extract has antibiotic properties. Root and leaf decoction treats diarrhoea, dysentery, and when taken with cumin and buttermilk treats urethral discharges. Root extract stops vomiting. Powdered root and pepper reduces toothache.)
Tylophora aposinata W. & A.	Given with milk to children to treat constipation; Given with honey to children to treat colds, reduce mucous, and to treat asthma. (Dried leaves and roots function as expectorant, diaphoretic, emetic, and cathartic.)
Hibiscus rosa sinensis L.	Flower is mixed with water to reduce mucous during colds, and lower body temperature due to fever; Serves as religious offering and hair decoration. (Plant contains a bland vascid mucilage that functions as a demulcent, emollient, and diuretic.)
Graptophyllum pictum (L.) Griff.	Treats skin and respiratory allergies; Food source; Source of green manure/mulch.

Appendix D--continued

Bulbophyllum sp.	Raw fruit is crushed with jaggery, heated, and then applied directly on cutaneous wounds in cattle to treat swelling and infection; Fruit is mixed with rice and given to milkcows to improve milk quality.
Gardenia gummifera L. *f.*	Pulverized powder is given to cattle to treat dysentery; Food source. (An anthelmintic that treats roundworm in livestock. The gum-resin functions as an anti-spasmodic, carminative, antiseptic, and stimulant. It is given to children during teething.)
Ixora grandiflora	Controls menstrual bleeding; Reduces body heat due to fever; Food source.
Ixora grandiflora var. black	Reduces sweating, vomiting, and involuntary loss of body fluids.
Aerua lanata Juss.	Treats dysentery; Source of green manure/mulch. (Root extract treats headache.)
Vitex negundo L.	Leaves mixed with garlic and corn to treat malaria; Mixed with cumin and tumeric powder to treat colds, fever, and throat infection in cattle; Treats skin and respiratory allergies; Pest control agent after pest outbreak; Fencing material. (Plant is aromatic, tonic, febrifuge, expectorant, and diuretic. Leaf decoction with *Piper longum* treats catarrhal fever. Leaves are smoked or made into poultices to treat headache, colds, swollen joints, and sprains. Leaf juice is applied to infected skin ulcers. Root decoction treats fever. Root bark tincture treats rheumatism.)
Calotropis gigantea (L.) Dryander ex Aiton f.	Root is mixed with tumeric and tied to right bicep for four to five days to treat fever; Treats skin inflammation and skin infections; Religious offering. (Root is taken as a purgative and to treat leprosy. Root charcoal and root bark is mixed with oil to treat skin eruptions, foul ulcers, leprosy. Root bark is mixed with rice vinegar into paste to treat filarial swelling of legs or scrotum.)

Appendix D--continued

Duranta plumeria	Fencing material.
Lawsonia alba L. var. *rubra*	Flowers, leaves, and shoots are mixed with milk to treat irregularity in menstrual flow. (Leaves and flowers treat headache.)
Randia dumetorum Lamk.	Root extract from mature trees is mixed with lemon juice and taken orally to treat snake bite; Fencing material. (Root and fruit treat snake bite. Root is ground with ox urine and applied as salve to the eyes of the patient. 10 to 30 grains of dried fruit pulp is given orally. Bark treats rheumatism and bone ache associated with fever. Fruit is an emetic and useful in treating bronchitis and asthma.)
Pandanus odoratissimus Roxb.	Treats joint pain; Hair decoration; Religious offering; Weaving material. (Male flowers treat earache, headache, and blood diseases. Leaves are said to treat scabies, smallpox, leucoderma, and leprosy.
Pandanus fascicularis	Leaves are crushed into plaster to treat dislocated limbs in cattle; Fencing and weaving material; Riparian erosion control. (Leaves are woven into mats, thatch, bags, etc. Leaf fiber is made into cordage. Keora oil from male inflorescence is a flavoring and perfume ingredient. Planted along canals to stabilize soil.)
Adhatoda vasica Nees	Leaves or roots are mixed with honey drink to treat colds, cough, asthma, reduce heat due to fever, and to purify the blood; Treats *Tinea* skin infections and other skin diseases; Fencing material; Source of green manure/mulch. (Leaves contain alkaloid vasicine that functions as expectorant and antispasmodic to treat cough, respiratory infections, tuberculosis, bronchitis, and asthma. Root and bark have similar uses to the leaves.)
Spondias mangifera L.	Food source; Stem is crushed and mixed with buttermilk to treat dysentery in cattle.
Fluggea virosa Willd.	Leaf green is dried, powdered, and mixed with milk to treat menstrual irregularity; Improves digestion.

Appendix D--continued

Carissa carandas L.	Root extract is mixed with calcium hydroxide (moist limestone) to treat toothache. (Root paste is used as fly repellent.)
Calycopteris floribunda Roxb.	Food source; Source of green manure/mulch; Weaving material.
Holarrhena antidysenterica (Roxb. ex Fleming) Wallich ex A. Dc.	Stem extract and fried, powdered seeds are mixed with buttermilk to treat stomach worms and stomach ache; Food source. (Fresh bark is excellent remedy for diarrhoea and amoebic dysentery. Seeds are effective in treating dysentery complicated with worms in children, diarrhoea, fevers, respiratory diseases, jaundice, colic, etc.)
Bambusa arundinaceae (Retz.) Willd.	One handful of green leaves given to cows eases the birth of calves; Fencing material; Weaving material; Construction material; Tender shoots are a source of food. (Leaves useful in stumulating mentrual flow, and for encouraging discharge of menses or lochia after childbirth. Leaves are mixed with black pepper and salt to check diarrhoea in cattle. Leaf buds treat threadworms. Young shoots contain 0.3 % hydrocyanic acid which is lethal to mosquito larvae.)
Anacardium occidentale L.	Leaf juice extract treats toothache; Treats uncontrolled sweating and vomiting; Food source; Religious offering; (Bark is used to treat sore gums and toothache. The spirit made from the fuit is diuretic and stimulant, and is locally applied in neuralgic pains and rheumatism.)
Pheonix silvestris (L.) Roxb. (*Phoenix acaulis*)	Infusion of fruit in milk is a tonic to restore health after illness; Food source; Weaving material.
Caryota urens L.	Bole is used to make the leveling bar on plows; Fencing material; Construction material.

Appendix D--continued

Emblica officianalis Gaertner	Dried and powdered fruit treats cough, mucous secretion, diarrhoea, and dysentery; Powdered fruit purifies water; Juice of fruit helps maintain the dark luster of hair. Plaster treats foot callus; Pest control agent after pest outbreak. (All tree parts are used medicinally. Fresh fruit is a rich source of vitamin C and also treats lung and eye inflammation. Fruit oil is reported to enhance hair growth. The dried fruit is an intestinal astringent, and treats diarrhoea, dysentery, and haemorrhage. Juice of the bark, honey, and tumeric are combined to treat gonorrhea.)
Diospyros melanoxylon Roxb.	Powdered leaves treat stomach infections; Food source. (Bark and fruit are useful astringents. Decoctions are effective cures for chronic dysentery, diarrhoea, and internal heamorrhages.)
Ficus aspermagara L.	Treats cattle illnesses; Source of green manure/mulch; Leaves are used as sandpaper/polishing material.
Gmelina arborea L.	Leaf juice extract is mixed with yogurt and taken orally to treat broken bones. The dosage is sixteen times more when used to treat cattle; Treats lumbar back ache; Bole is used to make leveling bar on plows. (Leaf extract is mixed with milk and sugar to treat gonorrhoea, catarrh of the bladder, cough. Leaf paste is applied to head to treat headache during fevers. Root and bark are bitter tonic, laxative, and treat indigestion.)
Semecarpus anacardium L. f.	Oil extracted from roasted nut is mixed with sugar and milk, and taken orally to treat stomach and intestinal worms; Treats foot callus; Pest control agent after pest outbreak. (Oil extracted from nut and nut shell is a powerful escharotic, antiseptic, cholagogue, cardiac and nerve tonic. Exuded nut oil is mixed with milk and taken daily to treat cough and to relax the uvula and palate. The bruised nut is an abortifacient when placed in the mouth of the uterus.)

Appendix D--continued

Annona squamosa L.	Treats cattle illnesses; Source of green manure/mulch; Food source. (Unripe fruit treats diarrhea, dysentery, and dyspepsia. Bruised ripe fruit is mixed with salt to hasten suppuration of tumors. Seeds applied to uterus induce abortion. Seed powder is a hair cleansing agent.)
Holigarna arnottiana Hoof. *f.*	Bark extract treats cattle skin infections; Source of green manure/mulch; Pest control agent after pest outbreak.
Anthocephalis cadamba Miq.	Treats body poisoning, such as tetnus infection. (Fruit juice with cumin and sugar is given for snake bite. Bark decoction treats fever. Mixture of bark juice, lime juice, opium, and alum treat eye inflammation.)
Saraca indica L.	Leaf extract is mixed with milk to improve fertility and to treat menstrual irregularity. (Leaves are considered to be alterative and useful in treating colic. Bark decoction is highly astringent and is a household remedy for hemorroids, internal bleeding, and uterine disorders - especially menorrhagia and leucorrhoea.)
Aporosa lindleyanna	Fruit reduces body heat/fever and nausea; Bark extract is a remedy for constipation and piles; Food source; Source of green manure/mulch.
Syzygium cumini (L.) Skeels (*Eugenia jambolanum*)	Tender leaves are chewed to extract juice, which treats stomach problems. Leaf fiber is spit out; Extract treats fever/chills and diarrhoea. Source of green manure/mulch. (Leaves are astringent, and are a remedy in dysentery with blood discharges. Tender leaf juice is mixed with goat's milk to treat diarrhoea in children. Seeds treat mellitus diabetes. Bark decoction is a mouthwash and gargle for spongy gums and oral infections

Appendix D--continued

Terminalia cebula (Gaertner) Retz.	Fruit pulp is ground with honey to treat bad coughs, excessive mucous, and tonsilitis; Food and oil source; Pest control agent after pest outbreak; Treats infections in cattle. (Fruit is astringent, purgative, and a safe laxative. Unripe fruit pulp is mixed with honey and aromatics like clove or cinnamon to treat flatulence, diarrhea, and dysentery. Infusion of fruit as gargle treats mouth infections, spongy and ulcerated gums.)
Cinnamomum zeylanicum Blume	Treats ear ache and helps drain ear infections; Food and spice source. (Functions as an aromatic, stimulant, and carminative to treat flatulence and spasmodic affections of the bowels. Bark powder infusion stimulates uterine muscle contractions in prolonged labor.)
Sapindus emarginata L.	Plaster treats skin infections in humans and cattle; Source of green manure/mulch; Shampoo for hair nourishment.
Careya arborea Roxb.	Bark extract treats heart disease; Food source; Source of green manure/mulch.
Artocarpus lacucha	Treats stomach worms and body lice; Food source; Construction material.
Strychnos nux-vomica L.	Leaf and bark extracts treat cutaneous (including mouth) ulcers in humans and cattle; Pest control agent after pest outbreak; Source of green manure/mulch. (Leaves are used in poultices over sloughing wounds and ulcers, even maggot-infested lesions. A few drops of bark extract treat cholera and acute dysentery. Powdered root bark is mixed with lime juice to treat cholera. Powdered seeds are effective treating neuralgia of the face, spasmodic diseases, epilepsy, and sexual impotence.)
Mytrigyne parviflora	Bole used to make leveling bar on plows; Construction material; Source or green manure/mulch.

Appendix D--continued

Buchanania latifolia Roxb.	Food source; Source of green manure/mulch. (Fruits and seeds are nutritous and good-tasting. Seed gum treats diarrhoea and is applied to glandular swellings in the neck. Ointment from kernel treats skin diseases, itching, and facial blemishes.)
Garcinia indica (Thouars) Choisy	Fruit treats body heat/acidity, nausea, and diarrhoea; Oil treats callused skin, especially foot callus; Food source; (Fruit is cooling, demulcent, antiscorbutic, cholagogue, and as an astringent is given to stop haemorrhage in the bowels. Oil treats ulcerations and fissures of the lip. Drink of infusion and its local application treat urticaria.)
Vateria indica L.	Resin is externally applied to treat skin diseases; Religious offering. (Bole resin treats gonorrhoea. External application of resin treats skin carbuncles. Seed oil dressing treats chronic rheumatism.)
Dillenia pentagyna	Treats disease in cattle; Food source; Construction material; Source of green manure/mulch.
Michelia chempaca L.	Bark extract treats stomach ache; Hair decoration; Religious offering; Construction material. (Bark decoction treats mild gastritis. Infusions of dried roots and root bark are purgatives. Flowers and fruits treat dyspepsia, nausea, and fever. Leaf juice is given with honey to treat colic.)
Cassia fistula L.	Tender leaf oil extract treats cutaneous inflamation, itch, and skin allergies. (Leaves have laxative properties, but are primarily an external emollient to treat ringworm, skin irritation, and to bring relief from dropsical swellings. Leaf poultices treat chilblains, rheumatism, and facial paralysis.)
Albizia Amara Boivin.	Construction material; Source of green manure/mulch. (Cools the body and treats erysipelas - skin inflammation, eye diseases, and ulcers.)

Appendix D--continued

Artocarpus integrifolia L. f.	Food and beverage source; Construction material; Religious offering. (Roasted ripe seeds are nutritous. Milky latex is mixed with vinegar to externally treat glandular swellings. Root extract treats diarrhoea. Tender leaves and root extracts treat skin diseases.)
Aegle marmelos (L.) Corr. Serr.	Leaf green aids digestion, treats diarrhoea; Bark treats chills/fever; Leaf juice is mixed with cow's urine to treat lice. (Leaf decoction is useful as febrifuge, expectorant, and anti-asthmatic. Ripe fruit treats diarrhoea, intestinal disorders, and some forms of dyspepsia characterized by both constipation and diarrhoea. Root bark decoction treats fever and heart palpitations.)
Casuarina equisetifolia L.	Construction material; Ornamental plant; Riparian soil erosion control agent. (Bark is slightly astringent and made into infusions to treat diarrhoea, dysentery.)
Acacia auriculiformis Cunn. ex Benth.	Construction material; Source of green manure/mulch after slow decomposition.

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BIOGRAPHICAL SKETCH

Donald Ian Flickinger was born in Lima, Ohio on July 8, 1956. He attended public school in Lima until age 14, when he enrolled at Deerfield Academy, Deerfield, Massachusetts. His junior year of high school was spent at the Franco-American Institute in Rennes, France through the School Year Abroad Program, Philips Academy, Andover, Massachusetts. In 1982, he earned a Bachelor of Arts degree in political science from Stanford University, Stanford, California. His junior year of college was spent studying at the Institut d'Etudes Politiques and Universite de Paris, France. In 1987, he earned a Masters of Science degree in wildland resource science from the University of California, Berkeley. From 1978 to 1984 he resided in Indonesia, undertaking community development work with both Volunteers in Asia, Inc., Stanford, California and with British Oxfam, Oxford, UK. In 1987, he came to the University of Florida to pursue doctoral study in both tropical forestry and community resource management. While at the University of Florida he has been a graduate assistant and done short-term consulting work in both Indonesia and India.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the Department of Geography in the College of Liberal Arts and Sciences and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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